THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE ENVIRONM T RY SPACE

INSIDE

SCIENCE OF SPORT

A-Z OF THE GALAXY

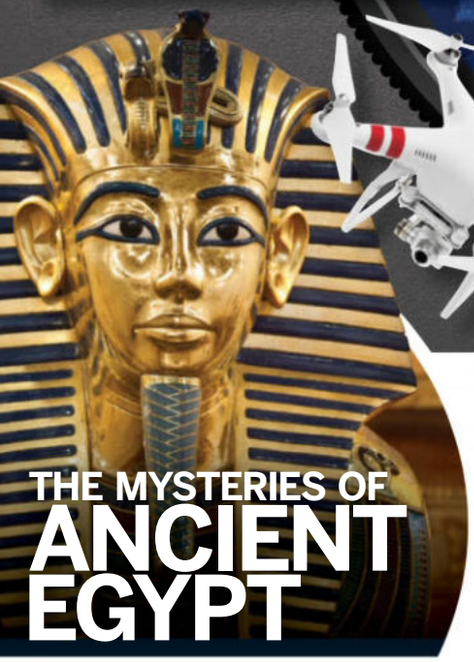
LIFE-SAVING TECHNOLOGY
6 medical devices you won't believe exist

DRONES

HOW UNMANNED FLIGHT WILL CHANGE YOUR LIFE

- PERSONAL AIRCRAFT
- SEARCH & RESCUE
- SAVING WILDLIFE
- DELIVERY

296 AMAZING IMAGES & CUTAWAYS INSIDE



THE MYSTERIES OF ANCIENT EGYPT

ARCTIC ANIMALS
How polar beasts take on the extremes and win

BACTERIA EXPLAINED
Discover why germs can survive absolutely anywhere

TREATING DIABETES
Find out how insulin controls your blood sugar levels

imagine PUBLISHING
DigitalEdition
GreatDigitalMags.com
ISSUE 68

+LEARN ABOUT ■ CLOUDS ■ SNAKES ■ INSECTS ■ TELEVISION ■ WHIPPET TANK

The ground breaking new M40 from Blue Aura

Always striving to innovate, Blue Aura introduces a new loudspeaker category, Stereo Bluetooth tower speakers

Upgrade TV audio using digital optical connection, stream music wirelessly from Tablets, Smartphones and Laptops using Bluetooth. Connect CD players, Tuners and Radios using audio cable

Now being demonstrated at the following stores: Sevenoaks Sound & Vision Chelsea, Adams & Jarrett St Leonards on Sea, Home Media Maidstone Kent

BLUE AURA

www.blueaura.co.uk

apt X csr

Bluetooth

N

ISSUE 68

WELCOME

The magazine that f

Page 68
Polar bears endure extreme weather on almost a daily basis – read about them and other hardy natural survivors

I wonder how many of you unwrapped a drone for Christmas? These unmanned flying machines are really taking off, with the marketplace for commercial drones worth an estimated £6.4 billion ($10 billion) by the end of 2014. They capture photos and video from angles we could never reach – and it's not just the home user that's taking advantage. Major media outlets are deploying their own drones for reporting news; conservationists are using them to catch poachers, and Amazon is developing a fleet to deliver your orders. Find out more on page 12.

Also in this issue, we take an alphabetical journey through the cosmos. There are no talking raccoons or dancing trees (as seen in Marvel's *Guardians Of The Galaxy*), but it's just as mind-bogglingly brilliant. Back down on Earth, we take you to some of the coldest places to uncover how animals survive the extreme temperatures (page 68), and get excited for sports season in our science feature that reveals the gruelling diet, training and recovery of the world's star athletes (page 34). So, on your mark…

Jodie

Jodie Tyley
Editor

Meet the team…

Andy
Art Editor
Don't underestimate the power of the Sun – it's going to be fuelling a plane around the world soon! Find out how on page 22.

Erlingur
Production Editor
It amazes me how much the world's top athletes have to eat just to fuel their exercise. Right, out to the gym. I want some cake.

Jamie
Staff Writer
You just won't believe how big space is, so we've picked out 26 of the best bits to show you.

Jackie
Research Editor
This month's history feature on Ancient Egypt is full of their weird and wonderful rituals. Find out how they lived and died on page 46.

Hannah
Assistant Designer
Ever wondered how animals survive the cold? On page 68 we look into how various creatures have adapted to live in this harsh environment.

Jo
Senior Staff Writer
Medicine is becoming increasingly high tech. Discover some of the incredible new gadgets being used to save lives on page 24.

What's in store

Check out just a small selection of the questions answered in this issue of How It Works…

How do water striders walk on water? **Page 41**

What are the different types of cloud? **Page 75**

How does road-noise cancellation work? **Page 20**

What is the iPhone 6 really made of? **Page 30**

What is the biggest mountain in the Solar System? **Page 66**

What's inside a British Whippet tank? **Page 56**

Follow us…

Facebook
How It Works magazine

Twitter
@HowItWorksmag

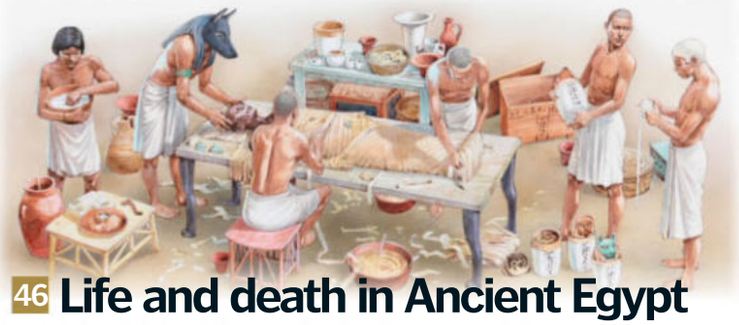
CONTENTS

12 DRONES

Discover how unmanned flight will change your life, from search and rescue to wildlife protection

12 Drones

24 Life-saving technology



46 Life and death in Ancient Egypt

Meet the experts...

Laura Mears
Science of sport
We watch sport for entertainment, but the biology, chemistry and physics behind body movement and throwing the perfect pitch is just as amazing. Find out how top athletes perform their best on page 34.

Ella Carter
Surviving the big freeze
This month, Ella explores how animals like seals and penguins survive without central heating! Did you know that polar bear skin is actually black? Find out more cool facts on page 68.

James Hoare
British Whippet tank
The Editor in Chief of **History Of War** and **All About History** takes us on a tour of the fastest British tank of WWI (page 56), as well as on-board a 16th-century Spanish galleon (page 52).

Jack Griffiths
10 cool things
Jack rounded up all the really cool stories from the realms of science, space, tech and transport in this issue's 10 cool things we learned this month over on page 10.

Steve Wright
Colour television
History buff Steve reveals the origins of colour television on page 54, where you can also find out what the first thing to be broadcast was. He also tells us how push-button telephones were invented.

REGULARS

How can smartphones control paper planes? Find out on pg 11

3D printing a lunar base

The first homes on the Moon could be built by robots

It would take about three Earth months to print the lunar base's protective shell

The European Space Agency has unveiled plans for a lunar base built by 3D-printing robots. Working with architects Foster And Partners, it has been testing the feasibility of printing with lunar soil and has created designs of what future Moon dwellings could look like. The basic support structure is made from an inflatable dome that can house up to four people. Robot-operated 3D printers then scoop up lunar soil and layer it over the dome to create a light but strong protective shell. This would keep the inhabitants safe from solar radiation, meteorites and the Moon's extreme temperatures, while an airlock helps to keep the living quarters pressurised.

The 3D-printed shell is made up of a hollow closed-cell structure – reminiscent of bird bones

The first 3D mission

A 3D printer has already made its way into space, but it's designed to print tools and replacement parts, rather than lunar homes. The International Space Station's new machine works by building up layers of heated plastic to create a three-dimensional object. The first object to be printed in space was a faceplate commemorating NASA and Made In Space Inc., the two companies that designed, built and tested the 3D printer. Any objects created by the machine won't be put to practical use just yet though, as they will first need to be analysed when they are returned to Earth in 2015. This analysis is needed to verify that the 3D-printing process works the same in microgravity as it does on Earth and that the objects created are safe to use on the space station.

The ISS's new 3D printer has already created the first object to be manufactured in space

Meet Sophie the Stegosaurus

150-million-year-old dinosaur goes on display at the Natural History Museum

Sophie, the world's most complete Stegosaurus stenops skeleton, has a new home in London's Natural History Museum. With 85 per cent of the bones intact, scientists have used CT (computed tomography) scans to make a computer model. They are using it to calculate the dinosaur's weight and eating habits. The entire specimen stands at 5.6 metres (18.4 feet) long and 2.9 metres (9.5 feet) tall, similar in size to a large jeep. It features over 300 bones and is believed to have been a young adult when it died.

The skull bones are detached from one another, allowing scientists to study it like never before

Future fuel

The first-ever poo-powered bus takes to the road

Running on biomethane gas generated through the treatment of sewage and food waste, the Bio-Bus is now ferrying passengers between Bristol Airport and Bath in the UK. The 40-seater bus can travel up to 300 kilometres (186 miles) on a tank of its renewable gas and the annual waste generated from one busload of passengers could power a return journey across the UK from Land's End to John O'Groats. Biomethane is generated through a process known as anaerobic digestion. The vehicle also produces fewer emissions than a traditional diesel engine, thus having a positive effect on local air quality.

Saving honeybees

Bees are fitted with tiny antennas to track their behaviour

Honeybees play an important role in the life of the countryside, but their numbers are falling dramatically. To find out why, scientists need to track their behaviour, but that's a difficult task when the average bee flies up to 6.5 kilometres (four miles) each day. To keep up with them, scientists at Rothamsted Research in the UK are using harmonic radar technology. First they glue a tiny two-centimetre (0.8-inch)-long antenna to a bee's thorax (back). A radar transmitter then emits a signal that is received by the antenna, before a component (harmonic) of it is reflected back. This allows the scientists to track the bee in real-time.

The antenna weighs a tenth of the bee's body weight so it is easy to carry

10 COOL THINGS WE LEARNED THIS MONTH

You can drive underwater

Looking straight out of James Bond, this sports car has the unique ability to travel on land and at sea. Costing a cool £1.2 million ($2 million), the Submarine Sports Car has lithium-ion batteries that power propellers and water jets and can reach speeds of 120 kilometres (75 miles) per hour underwater. Even more impressively, it doesn't produce any carbon emissions either!

Mice can be controlled with your mind

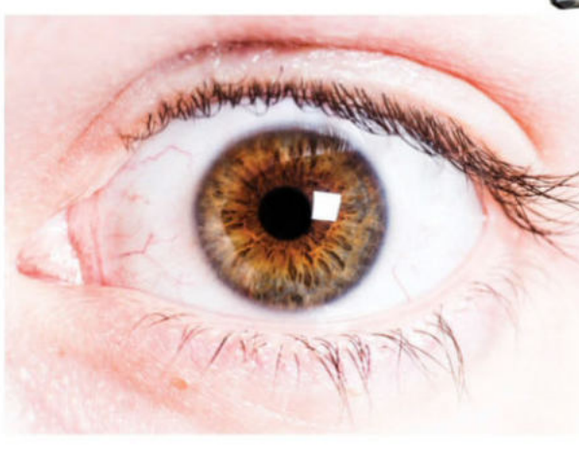
New developments in cybernetics have designed a way for humans to use their mind to control the protein levels in a mouse. By wearing a special wireless headset and changing their thought processes, a gene that controls the mouse's protein production can be altered.

Mary Rose's dog Hatch was male

The Mary Rose sank 469 years ago but its wreck still holds many secrets. Recent tests by scientists have discovered that the ship's dog, 'Hatch', was a male Jack Russell with a dark-brown curly coat. The hound's skeleton was unearthed on the raising of the ship in 1982, but Hatch was originally thought to be a female. However, a modern technique known as genomic DNA extraction has revealed the truth.

We can see invisible infrared light

It was previously believed that us humans had no way of sensing invisible infrared light, but scientists have now discovered that under certain conditions, we can. By firing powerful lasers that emit pulses of infrared light at the retina cells of mice and people, they found that rapid pulses gave a double hit of infrared energy, allowing the eye to detect it.



The first microscopic robot

Researchers at the University of Michigan are attempting to develop the world's first microscopic robots. These robots will be made from tiny electronically charged self-assembling particles. A type of nanotechnology, it is hoped that these tiny machines could fight disease in the body and defuse bombs.

Mars had a fireworks display

5 November wasn't observed just on Earth; it seems like Mars had its own galactic pyrotechnic show too. Only witnessed by a few rovers and orbiters, a comet flew within 140,000 kilometres (87,000 miles) from the Martian surface creating a bright yellow afterglow. As the comet Siding Spring passed, fireballs and cosmic dust fell to the planet creating the illusion of a celestial fireworks display.

Glowing highways exist

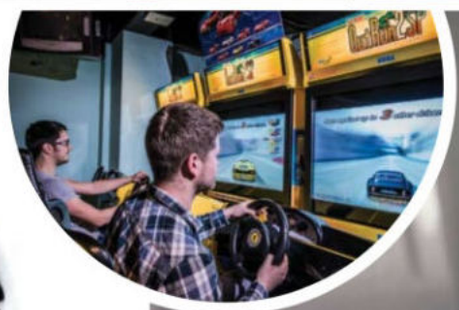
Road accidents could be drastically reduced with the new Smart Highway that will increase safety and visibility. Developed by Dutch company Heijmans, each road will be flanked by glowing lines that gather energy during the day and illuminate in nighttime hours. Currently only on a pilot scheme, perhaps more highways around the world might glow in the dark in the future.

There's a canine treatment for arthritis

Arthritis is a frequent condition for ageing people, but there could be a cure just around the corner. After being tested on dogs, results found that after treatment, the hound's paws became stronger. The formula is made from a simple mixture of plants and dietary supplements. It is hoped that this serum could be used on humans in the near future.

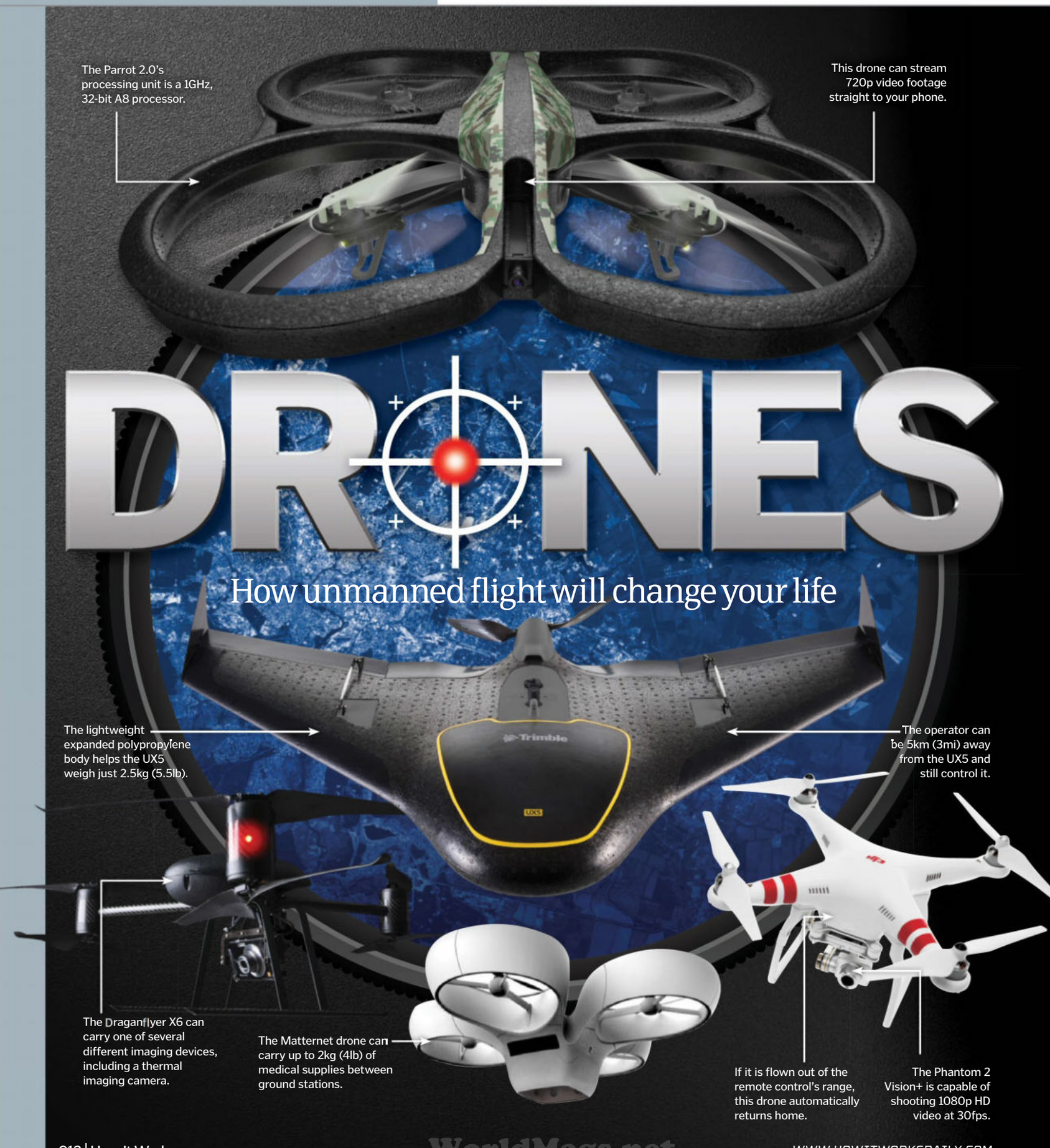
Smartphones can control paper planes

A classroom classic is joining the ranks of the technology revolution, presenting the smart paper plane! Known as the PowerUp 3.0, a battery and propeller is fitted to a paper plane, which is controlled by an innovative Bluetooth-powered app. With enough power to fly for ten minutes at a time and a range of 55 metres (180 feet), this contraption could be a good source of schoolyard pranks very soon!



Video games are educational

New research has found that playing action games such as *Call Of Duty* can improve motor skills and coordination. In the same way as riding a bike or playing sports teaches you new skills, video games aid the body's relationship between vision and muscle movement. So if you're procrastinating by playing your favourite game, remember that you could still be learning new skills!



Also known as
1 The name drone refers to any aircraft without a pilot on board. They are also known as unmanned aerial vehicles (UAVs), remote piloted aircraft (RPA) or unpiloted air systems (UAS).

Future swarms
2 There are over 4,000 different UAVs in circulation on the global market and the FAA estimates that as many as 7,500 small commercial drones could be operational in US airspace by 2020.

Friendly drones
3 In Britain, manufacturers have suggested painting drones in bright colours as a way to make them appear friendlier and less reminiscent of warzones.

The first drone
4 The first powered UAV was the "Aerial Target" invented by Archibald Montgomery Low in 1917. It was launched using compressed air from the back of a lorry.

Control methods
5 Drones can be controlled in one of two ways; either autonomously by an on-board computer, or remotely by a pilot on the ground.

DID YOU KNOW? *The number of organisations allowed to use drones in the UK is up 80 per cent from start to end of 2014*

Drones offer a whole new perspective on video recording and photography

Drones are being used in air forces around the world, but the future is looking much more varied for the remote controlled aircraft. There is a fast-growing industry of autonomous flight that can both help and entertain the world, from rescuing people at sea to recording awe-inspiring aerial videos.

Disaster relief, for example, is a major area where drones can make an incredible difference. They can fly over the scene of an earthquake, nuclear meltdown or bomb site and capture high-resolution pictures or video to help the team on the ground organise a rescue or clean-up mission. Drones such as the Trimble UX5 could be of enormous benefit as the 2.4-gigahertz modems in the craft and the tablet can communicate over a distance of five kilometres (3.1 miles), enabling mapping to take place with the pilot nowhere near potentially dangerous rubble and aftershocks.

When the Fukushima nuclear power plant malfunctioned in March 2011, clean-ups and analysis of the radiation was limited due to the health risks posed to helicopter pilots.

Drones such as the Advanced Airborne Radiation Monitoring (AARM) system designed by Dr James MacFarlane at the University of Bristol could put an end to that. This particular craft is a hexacopter with a gamma spectrometer attached, which measures the amount of radiation being emitted from a chosen site. This can be done without a human anywhere near the area, so information can be received much more quickly and safely.

One of the most exciting commercial applications of drones is aerial photography and videoing. In the past, shooting any kind of media from the air required the hire of cranes or helicopters. Now, however, drone-mounted cameras can be bought for as little as £50 ($80), enabling amateur photographers and film-makers to capture amazing high-definition footage for a fraction of the cost.

Although drones might seem the futuristic domain of governments, the military and serious enthusiasts, there are a number of extremely practical day-to-day applications they can be used for. Amazon and DHL are both deep into the testing stage of delivery drones. You may remember the end of 2013 when Amazon claimed drones would be delivering small packages within five years.

Currently the use of drones for commercial purposes is banned in the United States, but Amazon has petitioned the Federal Aviation Authority (FAA) to relax their rules to allow small drones to carry payloads of 2.3 kilograms (five pounds) to customers. This weight, they say, makes up 86 per cent of their deliveries and would take big, bulky and dangerous delivery vehicles off the road. DHL has already flown test missions from the German mainland to the island of Juist, off its northern coastline.

Commercial drones are a far cry from their headline-grabbing military cousins, but they are every bit as exciting, packed with fascinating technology and the ability to perform tasks that makes our lives, and the world, a little bit safer and a whole lot more fun. ▶

The AARM won its inventor, Dr James MacFarlane, the 2014 ERA Foundation Entrepreneurs Award

"Draganflyer drones are being used to provide a unique high-resolution view of disaster zones"

LIFE-SAVERS

Discover the innovative drones designed to rescue those in need

The agility and efficiency of these incredible machines often means they are better equipped than humans or other vehicles for humanitarian tasks . From transporting aid to spotting someone in need, there is a variety of potentially life-saving drone aircraft projects that are currently in development.

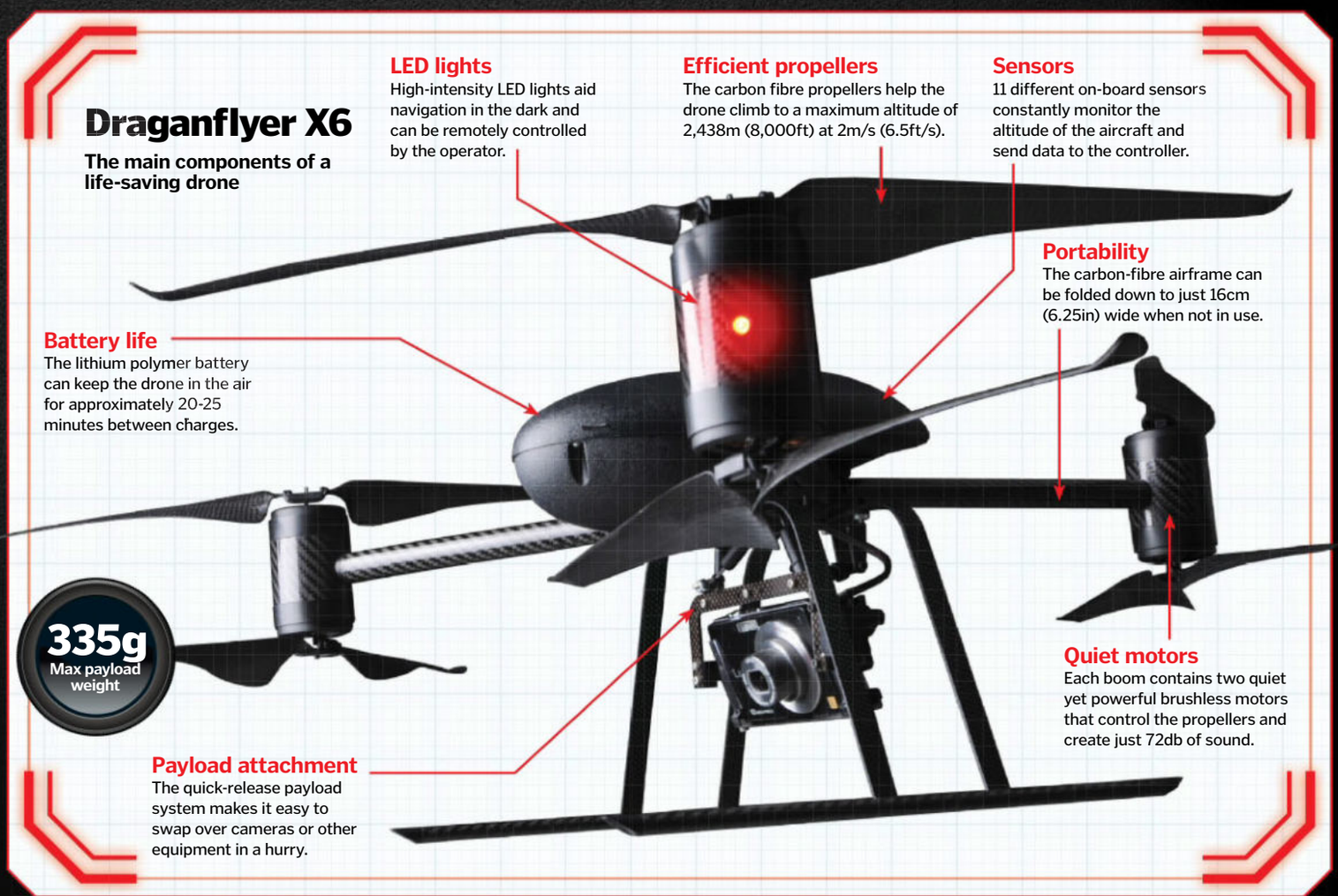
One such initiative is the LifeLine Response app, a personal panic button that will summon a drone if you are in distress. If you are concerned about your safety, you can simply load the app and keep your thumb pressed on the screen or set a timer. If you get into trouble, you can release your thumb or fail to deactivate the timer, and the police will be called and a drone deployed to your location using GPS.

The idea is that the drone, which can travel at 97 kilometres (60 miles) per hour, will be able to scare off an attacker by sounding an alarm, follow them if they flee the scene, and collect information from the area before the police arrive. It is hoped the system could be used in cities across the world, with dozens of drones stationed at each law-enforcement headquarters waiting to spring into action.

Another concept, developed by Dutch engineering student Alec Momont, involves 'ambulance drones' quickly delivering defibrillators to heart-attack victims. The drone would be able to transport the equipment within minutes, and then the operator can use two-way video supported communication to instruct a nearby helper to use it.

While some life-saving drones are still a work in progress, others are already being put to work. For example, Draganflyer drones are being used to provide a unique high-resolution view of disaster zones and crash sites to help teams on the ground locate victims, organise rescue missions and document the scene.

Draganflyer makes several different models of drone suited to both hobbyist and professional applications. These come with a choice of camera, including a GoPro and thermal-imaging camera, and are flown using a handheld controller, but you will need some training in order to operate one. ▶

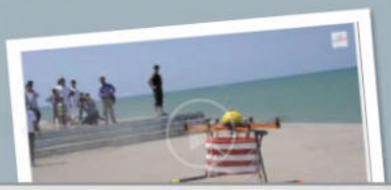


AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

Watch the Pars drone race a human lifeguard

www.howitworksdaily.com



DID YOU KNOW? *85 per cent of roads in sub-Saharan Africa are inaccessible in the wet season, making drone delivery useful there*

Draganflyer story

We spoke to Kevin Lauscher from Draganflyer about the incredible innovations of the X6

What is the main purpose of the X6?
The Draganflyer X6 was developed as a safe and easy-to-use platform to carry an aerial imaging system that provided clear high-resolution images. At the time of development, systems that could carry a high-resolution camera were generally large, dangerous and difficult to control.

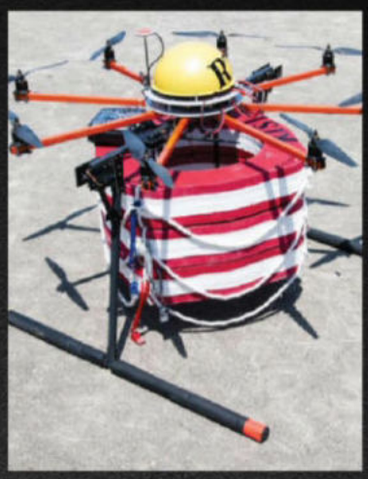
What sets it apart from other drones in existence?
It has a unique design with six rotors in the Y-style configuration, as well as its ability to fly even if it is missing one of the rotors. When it was first released, the concept of using sUAS (Small Unmanned Aircraft Systems) for civilian purposes was practically unheard of, so the attention it received made it stand out from other models.

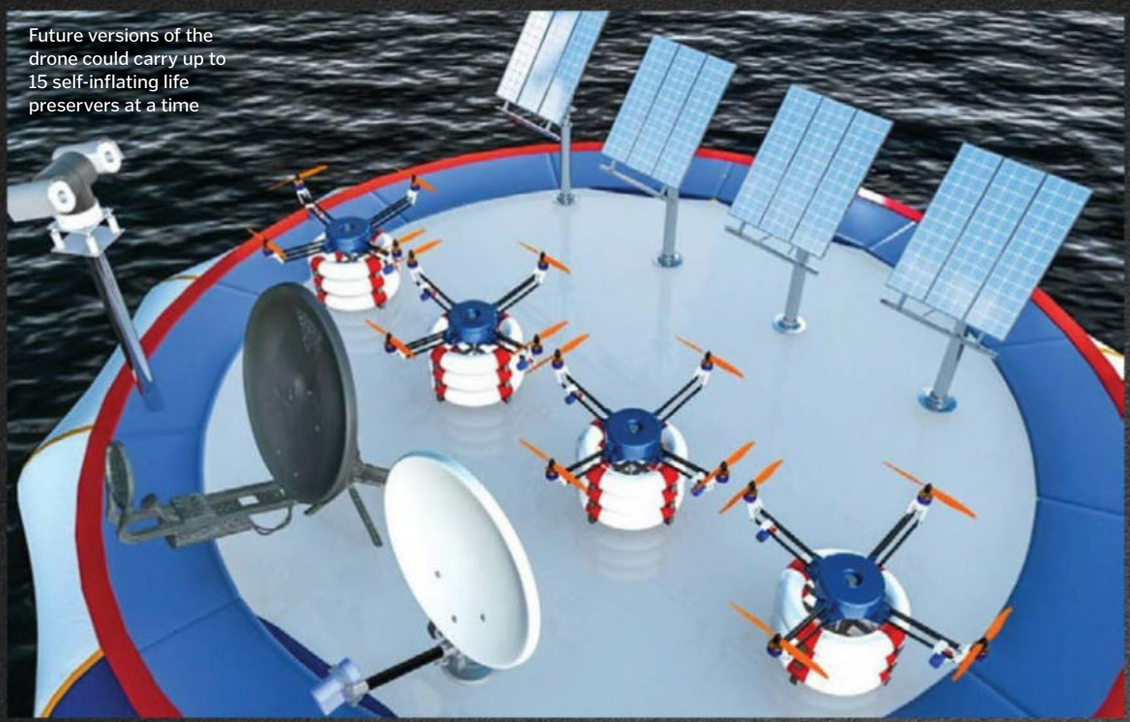
What are your hopes for the X6 in the future?
The Draganflyer X6 was our first industrial system and was responsible for setting a lot of firsts for the industry. Since then we have developed other improved systems based on our experience with the X6. Our hopes are to work some technology upgrades into its design and for it to again become a front-runner in the sUAS world.

The Draganflyer X6 can carry cameras weighing 335g (11.8oz) or less, including a GoPro

LIFEGUARD DRONE

Getting help to those in trouble out at sea is especially difficult and slow, particularly in adverse weather conditions. Iranian company RTS Lab hopes drones can solve this, as it is currently developing a new lifeguard robot called Pars. After hearing about the huge number of people that drown in the Caspian Sea each year, RTS Lab decided to create a multirotor drone that could help save human lives. As well as being able to fly above the water and be guided by GPS, Pars can also carry and drop life preservers to where they are needed. Although it is not able to pull people to safety, it can provide initial aid before the lifeguard arrives and monitor the situation by recording photos and video. A prototype has already been tested, and was able to reach a target 75 metres (246 feet) out to sea in just 22 seconds, while a human lifeguard took over a minute.

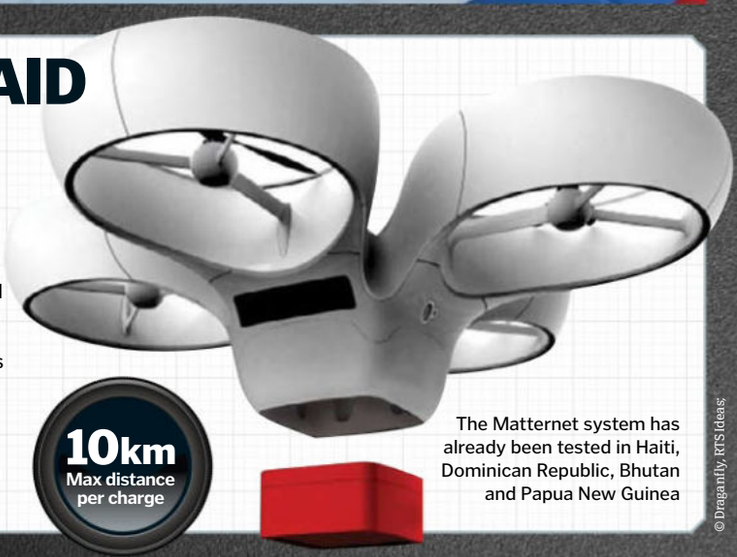




Future versions of the drone could carry up to 15 self-inflating life preservers at a time

DELIVERING AID

In many developing countries, rural roads become inaccessible during the rainy season, making it very difficult to transport much-needed medicine to those in need. Matternet – a network for transporting matter – aims to provide the solution. The plan involves autonomous drones, carrying up to two kilograms (4.4 pounds) of medical supplies, flying between several ground stations. These stations would allow the drones to collect or drop off their payload as well as swap batteries so they can keep flying for longer. The drones will use GPS and other sensors to navigate and an operating system would make sure they avoid adverse weather conditions and do not collide with each other.



The Matternet system has already been tested in Haiti, Dominican Republic, Bhutan and Papua New Guinea

"Some big blockbusters, such as Skyfall, have already been shot using unmanned drones for aerial footage"

The Parrot AR.Drone 2.0 is controlled via an app on your Android or Apple device

COMMERCIAL USE

The drones offering film-makers a whole new perspective

Drones such as the Parrot AR and the DJI Phantom 2 Vision+ have added a thrilling new dimension to personal photography and filmmaking. These clever gadgets are becoming more and more affordable for amateurs looking to capture Hollywood-style footage from unique angles. A Parrot AR. Drone, for example, will only set you back around £320 ($300) and has a built-in camera that can shoot 720-pixel high-definition video. It generates its own Wi-Fi hotspot so you can control it from up to 50 metres (165 feet) away via an app on your smartphone or tablet. The app also shows a live stream of the video being captured and lets you change its direction by simple tilting your device. It can even perform impressive flips in mid-air, and you can program automatic movements to compose your film like a professional director. If you do happen to crash the drone while filming a daring action sequence, then you can have a go at repairing it yourself as all of the parts and instructions are available online. Due to the relatively recent advancement of commercial drone technology, many countries are still developing laws regarding their use in public spaces. In the United States, the Federal Aviation Administration currently limits drones to be flown below 122 metres (400 feet), away from airports and air traffic, and within sight of the operator.

Using drones in a professional capacity requires a certificate of approval from the FAA, but it has recently granted six movie and television production companies permission to use drones on their sets. Some big blockbusters, such as *Skyfall* and the *Harry Potter* movies, have already been shot using unmanned drones for aerial footage, but filming took place in countries where this was allowed.

We are already seeing more and more drone-shot sequences on the big screen. Not only is this great news for us cinemagoers, as we will be treated to more creative camera angles, but it will also save the production companies a lot of money on helicopter and crane bills as they try to get above the action while filming. ▶

AR.Drone teardown

The incredible Parrot AR. Drone 2.0, bit by bit

420g
Max weight

Battery
The drone is powered by a 1,000mAh 11.1V lithium polymer battery. It only lasts 12 minutes, taking 90 to charge.

Motors
When accelerating, the motors that turn the propellers rotate at 41,400rpm, dropping to 28,000rpm when hovering in place.

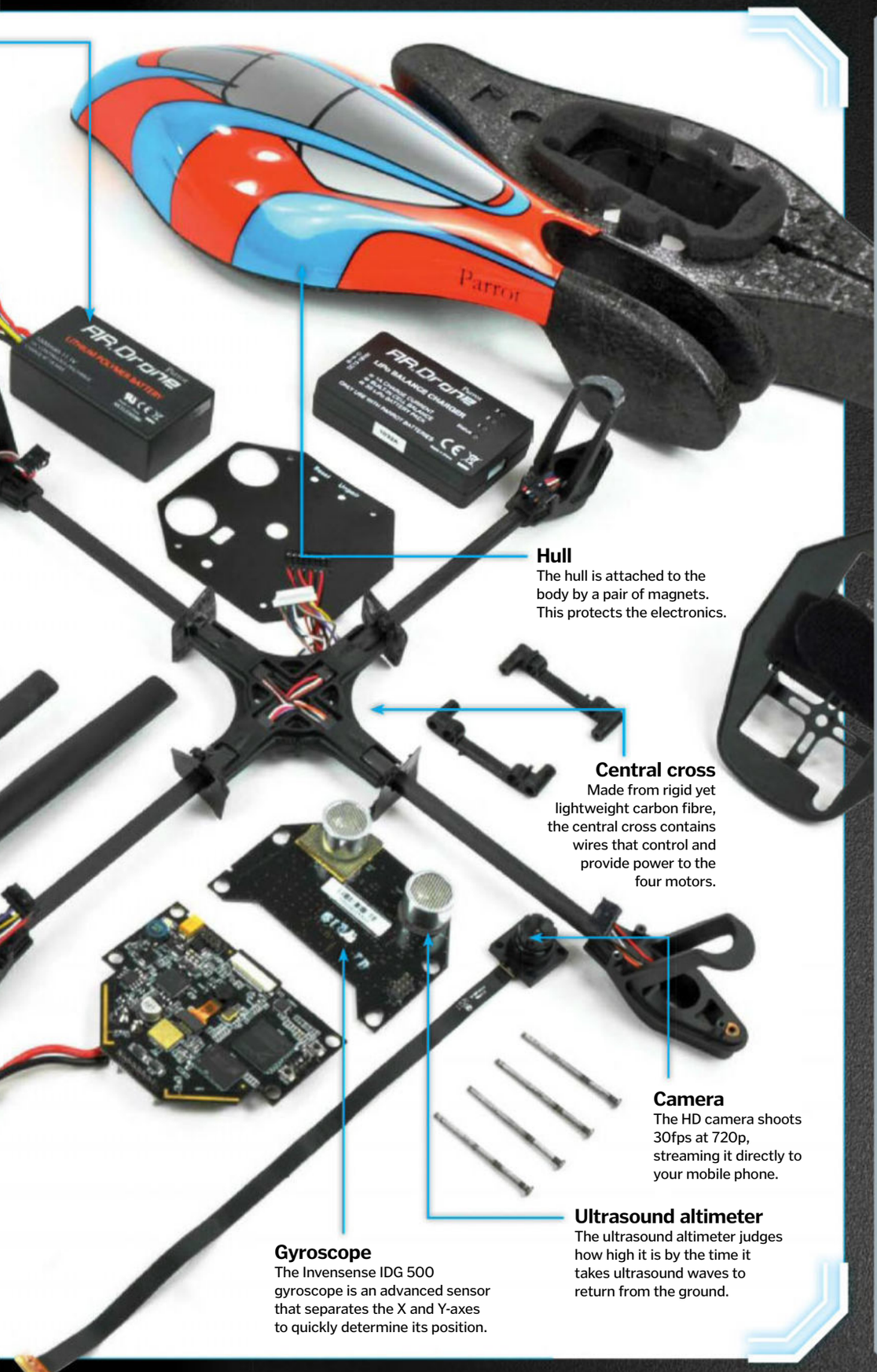
Propellers
The propellers won a design competition run by the French Army. They can spin either clockwise or anti-clockwise depending on their position.

14 DAYS

LONGEST DRONE FLIGHT

The solar-powered Zephyr drone developed by UK firm QinetiQ flew for 14 days and 22 minutes in 2010, breaking the world record for the longest drone flight.

DID YOU KNOW? *TV coverage of skiers and snowboarders at the 2014 Winter Olympics in Sochi was shot by unmanned drones*



Hull
The hull is attached to the body by a pair of magnets. This protects the electronics.

Central cross
Made from rigid yet lightweight carbon fibre, the central cross contains wires that control and provide power to the four motors.

Camera
The HD camera shoots 30fps at 720p, streaming it directly to your mobile phone.

Ultrasound altimeter
The ultrasound altimeter judges how high it is by the time it takes ultrasound waves to return from the ground.

Gyroscope
The Invensense IDG 500 gyroscope is an advanced sensor that separates the X and Y-axes to quickly determine its position.

BEST FOR... VIDEO STREAMING

DJI Phantom 2 Vision+
Price: £940/$1299 • **Get it from:** www.dji.com

BEST FOR... EVERYDAY FUN

Parrot MiniDrone Rolling Spider
Price: £90/$100 • **Get it from:** amazon.co.uk

BEST FOR... BEGINNERS

Walkera QR Ladybird V2
Price: £60/$89 • **Get it from:** walkera.com

BEST FOR... STUNTS

Blade 350 QX V2
Price: £340/$575 • **Get it from:** quadcopters.co.uk

BEST FOR... AFFORDABILITY

Hubsan X4 H107
Price: £45/$70 • **Get it from:** amazon.co.uk

"Drones would be useful for monitoring the rhino, as well as protecting them"

ANIMAL PROTECTORS

Drones are revolutionising the way wildlife conservationists keep poachers at bay

As well as helping to save the lives of humans, drones can also come to the rescue of animals in the wild. The Ol Pejeta Conservancy in Kenya is East Africa's largest black rhino sanctuary but has lost several rhinos to poachers in recent years. They have now teamed up with drone company Airware to see if unmanned aircraft can help protect this endangered species. A prototype Aerial Ranger drone, featuring a camera that can deliver real-time video and thermal imaging to a team on the ground, has been tested during the day and night to respond to poaching incidents. Ol Pejeta only has around 150 rangers, each having to cover 2.4 square kilometres (0.93 square miles) of the 364-square-kilometre (140.5-square-mile) sanctuary. This makes response times to poaching incidents very slow, but using a drone allows them to get there immediately and record footage of the offending individuals to use as evidence in court and deter further attacks.

The drones would also be useful for monitoring the rhino, as well as protecting them. It would allow Ol Pejeta to conduct their annual wildlife census more regularly and cheaply, helping them to reliably keep track of the ecosystem.

Microsoft has also ventured into animal-tracking drones with their ZooTracer project. It involves attaching tiny GPS tracking and sensing devices, weighing just seven grams (0.25 ounces), to animals. These devices can record all sorts of data, such as the animal's speed, and then a drone is deployed to the animal's location to get the data back and monitor the animal further.

Ol Pejeta is home to three of the six remaining northern white rhino in the world

THE STATS
TRIMBLE UX5

FLIGHT TIME **50min**

MAX ALTITUDE **750m**

SPEED **80km/h**

WINGSPAN **100cm**

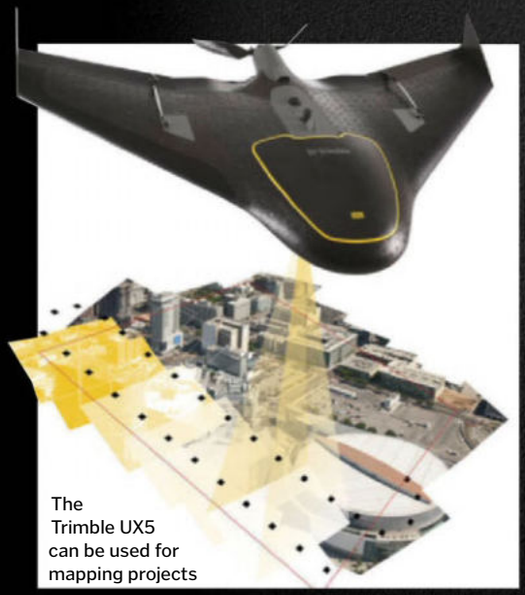
WEIGHT **2.5kg**

DID YOU KNOW? *California's Casa Madrona Hotel uses drones to deliver champagne to guests in their $10,000-a-night luxury suite*

The impact-resistant foam structure makes the Trimble UX5 extremely durable and strong

AERIAL MAPPING

The drones making difficult jobs so much easier



The Trimble UX5 can be used for mapping projects

The advancements in drone technology have been extremely beneficial for industry. From engineering and surveying to mining and agriculture, a variety of markets are embracing this new tool to improve day-to-day operations. The Trimble UX5 is one of the leading surveying and mapping drones being used by many companies. It features a 16.1-megapixel camera for taking several overlapping high-resolution images, which are then layered together by specialist image-editing software to collate a map. By taking several photos from different locations, triangulation can be used to determine accurate coordinates and create three-dimensional plans of the area free from distortion. This proves invaluable when planning new infrastructure, inspecting mines and monitoring forests, and because the drone is autonomous and unmanned, it provides a much safer, quicker and cheaper solution than the pilot-controlled alternative. Plus, it is made from expanded polypropylene, a durable material that enables it to fly in practically any weather and even float on water.

The Trimble UX5 takes off from an angled launcher that helps it safely clear the ground and climb into the air, where it then flies a preplanned route travelling back and forth over the area. An application on the Trimble Tablet Rugged PC is used to plan flights and operate the drone easily and reliably, but once in the air it uses GPS to navigate. When its flight is over, the drone automatically begins its landing sequence, circling above a preplanned landing spot and using reverse thrust to help it land in tight spaces.

DELIVERY DRONES

Although commercial drones are mainly being used by specialist industries, consumer companies certainly haven't failed to notice their potential. In the not-so-distant future, the skies above us could be swamped with a network of drones delivering our shopping, or even fast food, straight to our front door. Many big companies are testing this new delivery method, but it is likely to be several years before the idea becomes reality. Many countries, including the United States, do not allow drones to be flown at low altitude over residential areas, and the autonomous aircraft currently have no way of avoiding obstacles en route.

Amazon Prime Air

Amazon is already developing and testing drones for delivering packages weighing up to 2.3 kilograms (five pounds) to customers within 30 minutes of ordering. The retail giant is just waiting for permission from the FAA before it can roll out the new system, which is expected to happen in 2015.

DHL parcelcopter

Logistics firm DHL is the first company to launch a drone-based delivery service. Its 'parcelcopter' is currently being used to deliver small parcels to the German island of Juist in the North Sea. A restricted flight area has been established for the service, which mainly delivers medication and other urgently needed goods.

Burrito Bomber

The Burrito Bomber is a Mexican food-delivery system that lets you place your order via an app. A drone will then fly to your location and parachute your snack down to you in a custom-made Burrito Delivery Tube. It should be up and running – in the US, at least – once the FAA updates its regulations.

"An algorithm creates inverse sound waves through the car's speakers to cancel out the road noise"

Road-noise cancellation

This new acoustic technology could spell the end for road noise in cars

Now there's a way of eliminating road and tyre noise without using headphones. The Road Noise Cancellation (RNC) system is the brainchild of audio giant Harman and British automobile makers Lotus and it works by fitting accelerometers into the chassis of the vehicle. These identify and monitor the frequencies of unwanted tyre noise and relay the information back to a controller. An algorithm in the controller creates inverse sound waves through the car's speakers to cancel out the road noise.

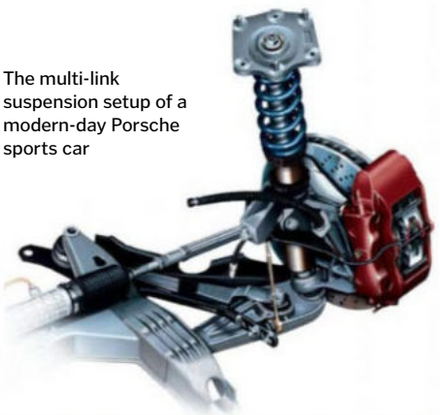
The cause of the droning sound is the car's design. Gone are the unsightly box-shaped vehicles that accelerate slowly and lurch around corners with a marked lack of balance and finesse. In their place, we now have cars with a host of chassis evolutions including multi-link suspension and a lower centre of gravity, ensuring comfort and balance on a bend with little body roll. However, the caveat to these evolutions means that multiple noise paths fill the cabin where passengers are trying to relax. This unwanted noise is only amplified further by bigger, more aesthetically pleasing wheels, meaning lower-profile tyres (which create more noise) need to be fitted to ensure they fit within a car's wheel arches. Not only does RNC technology hope to combat this issue, but it's also designed to improve fuel economy, as it enables car manufacturers to use lighter materials that would normally increase the noise inside the vehicle. Simple yet effective, this could soon be rolled out to a host of mainstream manufacturers, improving the experience of the occupants – particularly on those long journeys!

What is multi-link suspension?

Utilised on the rear axle of a car, multi-link suspension is an advanced form of suspension on a motor vehicle that helps to increase a car's agility against a number of adverse directional forces and interference during driving.

The system works by a number of transverse and longitudinal links being attached to each independent wheel of a car via the wheel hub. These various links hold the wheel firm against a variety of forces – for example when the suspension is compressed – ensuring the wheel's camber, toe and castor angles are largely unaffected over rough or uneven surfaces. This helps better improve stability and comfort in a car.

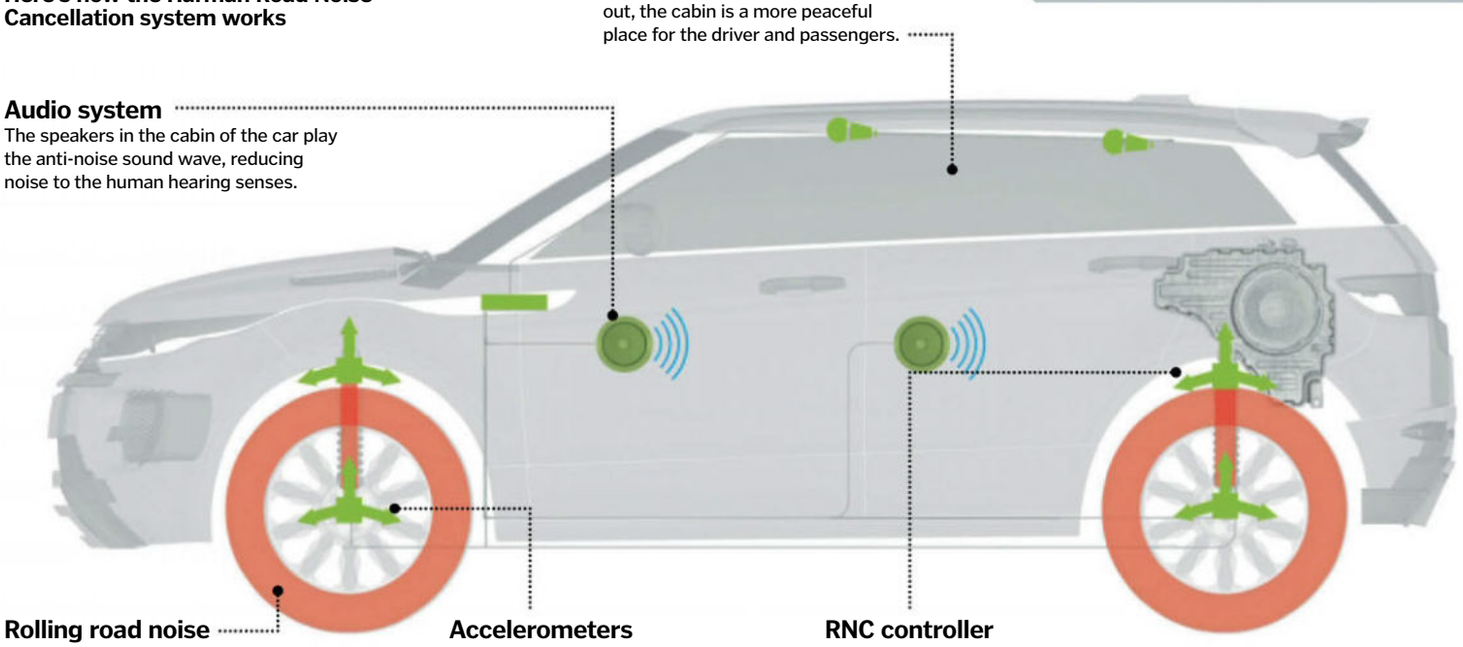
Although the system is complex and involves many components, multi-link is considered lightweight compared to other suspension configurations, which also helps boost a car's agility and – ultimately – its performance.



The multi-link suspension setup of a modern-day Porsche sports car

The system in action

Here's how the Harman Road Noise Cancellation system works



Quiet zone
With rolling road noise cancelled out, the cabin is a more peaceful place for the driver and passengers.

Audio system
The speakers in the cabin of the car play the anti-noise sound wave, reducing noise to the human hearing senses.

Rolling road noise
Low-profile tyres generate noise and vibrations as the vehicle is in motion.

Accelerometers
These are placed in the chassis near the wheel hubs and provide a frequency of the rolling road noise.

RNC controller
This takes the frequency information provided by the accelerometer and generates an anti-noise signal, which is sent to the speakers.

Xduro AMT pro 27.5

27.5", All Mountain, 150mm travel, 4-Link System • Bosch Performance 36 Volt, 250 Watt Motor, 60Nm Torque
Lithium Ion 400Wh Battery, max range 175km • Bosch Intuvia Display • Sprocket Equalizing System • Gravity Casting Interface • Skid Plate Motor Protection
Fox 34 Talas CTD Adjust FIT 120-150mm / Fox CTD Kashima • Sram X01 11-speed • Avid X.0 Trail Hydraulic Disc Brakes • Crank Brothers Iodine 3 Wheelset • 21.1kg

FIND YOUR NEAREST HAIBIKE STOCKIST AT: WWW.HAIBIKEUK.CO.UK WWW.FACEBOOK.COM/HAIBIKEUK @HAIBIKEUK

"Despite being wider than a Boeing 747 Jumbo Jet, the whole aircraft weighs only as much as a car"

Solar flight

Find out how the Solar Impulse will fly around the world without a drop of fuel

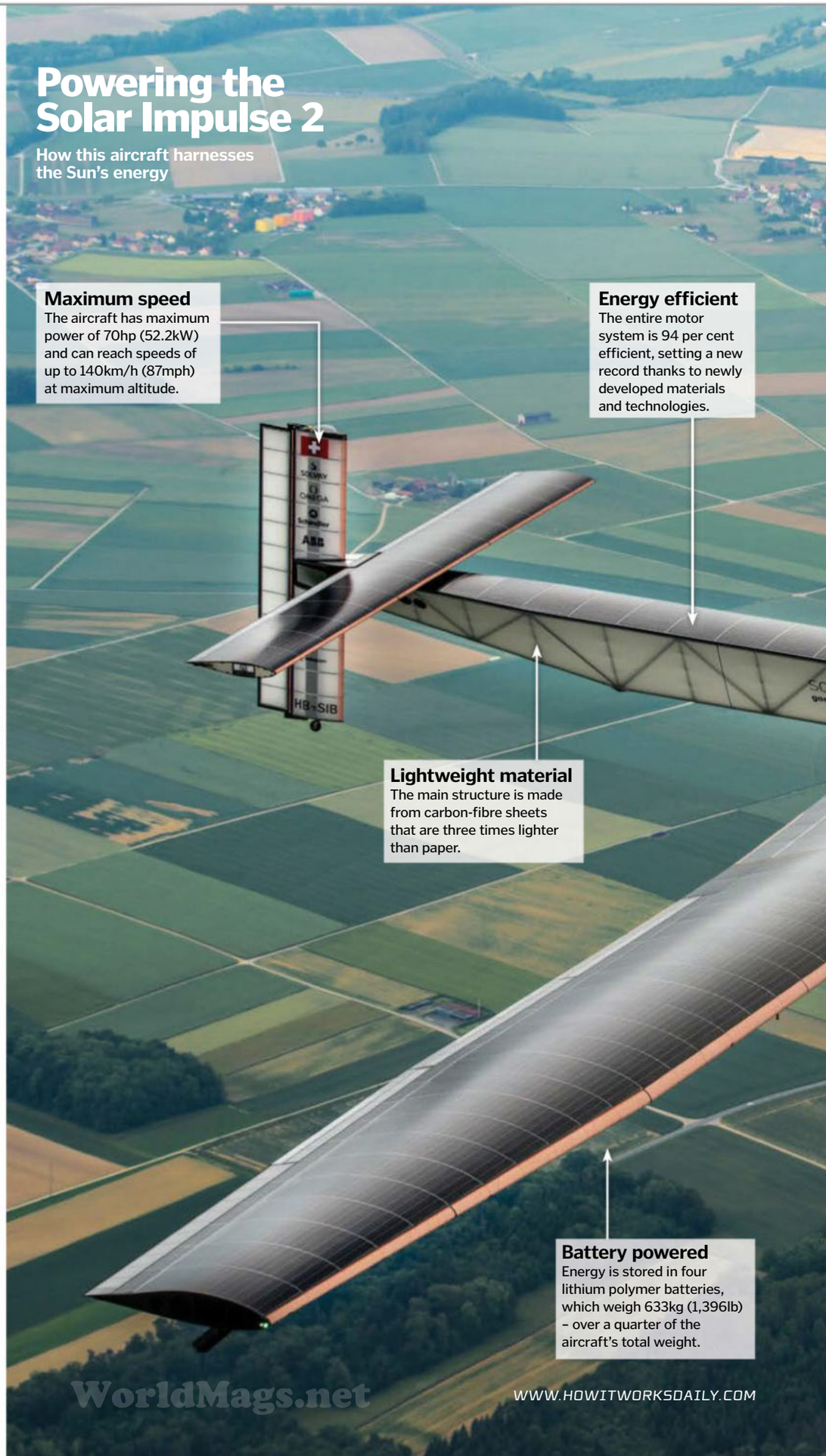
In March 2015, the first-ever round-the-world flight powered only by solar energy is set to take off. The Solar Impulse 2 will start its mammoth journey in Abu Dhabi, flying over oceans and continents before landing back where it started. The whole flight is expected to take around 500 hours or just over 20 days, but this will have to be split into approximately ten separate flights spread over five months.

Despite its unlimited energy supply, the aircraft's ability to complete the mission without stopping is prevented by the pilot's need for rest and a limited space for food supplies. Taking turns at the controls will be Solar Impulse initiator and chairman Bertrand Piccard and cofounder and CEO André Borschberg. Flying over the Pacific and Atlantic Oceans will require the pilots to stay in the air for up to five days and nights at a time, putting their endurance to the test.

The Solar Impulse 2 works by turning sunlight into electric energy using the vast number of solar cells stretched across its enormous 72-metre (236-foot) wingspan. Despite being wider than a Boeing 747 Jumbo Jet, the whole aircraft weighs only 2,300 kilograms (5,071 pounds) – less than a Land Rover Discovery jeep – helping it climb to a maximum altitude of 8,500 metres (27,890 feet). At night it will drop to 1,500 metres (4,920 feet) to conserve as much of the energy stored in the four batteries as possible. The large wingspan not only makes the aircraft very difficult to manoeuvre, but also means it is very sensitive to turbulence. If it tilts (banks) by more than 5 degrees it could go into a spin, but the pilot is notified by a vibration alert if the maximum bank angle is exceeded. To avoid turbulence and winds of more than seven knots (13 kilometres [eight miles] per hour), all takeoffs and landings will be scheduled at night.

Powering the Solar Impulse 2

How this aircraft harnesses the Sun's energy



5 TOP FACTS
SOLAR IMPULSE

Family tree
1 Chairman Bertrand Piccard comes from a long line of explorers. His grandfather was a balloonist and his father explored the deepest part of the world's oceans.

Solar-power inspiration
2 Piccard made the first nonstop round-the-world balloon flight in 1999. Finishing with just 40kg (88lb) of fuel left inspired him to create a fuel-free aircraft for his next trip around the globe.

The prototype
3 Solar Impulse 1 had a smaller cockpit with no toilet so could not be flown for as long. In March 2015 it will go on display in a Paris museum.

Major setback
4 Solar Impulse 2 experienced a setback in 2012 when the wing spar broke, setting the round-the-world mission back by a year. The team took this opportunity to fly Solar Impulse 1 across North America.

Weather forecast
5 Solar Impulse 2 will take off for its round-the-world mission in March so that it can avoid the monsoon season when flying over India.

DID YOU KNOW? *If you want to be a part of the Solar Impulse 2 mission, you can adopt one of its solar cells*

Solar cells
17,248 solar cells, each 135 microns thick – about the thickness of a human hair – convert sunlight into electric energy.

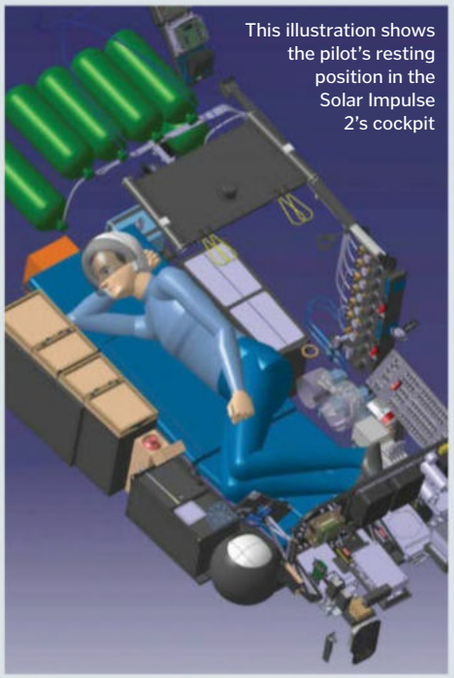
Storing energy
The batteries can store 260Wh/kg and can be fully charged in just 3-4 hours when the aircraft is grounded.

Creating thrust
The four motors each generate 17.5hp (13kW) of power, rotating the 4m (13.1ft)-diameter propellers to create thrust.

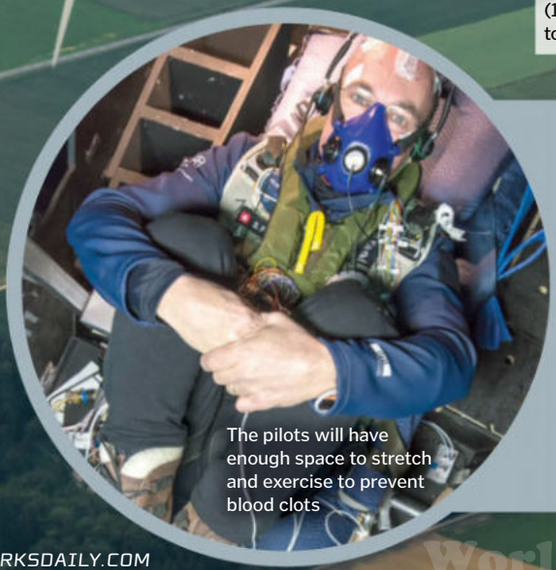
Inside the cockpit

The 3.8-square-metre (40.9-square-foot) cockpit will be each pilot's home for up to five days and nights at a time. It can store the 2.4 kilograms (5.3 pounds) of food, 2.5 litres (0.7 gallons) of water and one litre (0.3 gallons) of sports drinks they will need to consume each day, plus enough oxygen to survive in the unpressurised cockpit. Temperatures will fluctuate between +40 and -40 degrees Celsius (-40 degrees Fahrenheit) while in the air, so the cockpit is insulated with isolation foam, and the pilot's clothing contains intelligent nylon fibres to stabilise their body temperature.

The multipurpose seat contains the toilet, parachute and life raft, plus it can lie flat to allow the pilot to stretch their legs. A matchbox-sized electrocardiogram will monitor the pilot's fatigue and vigilance and a tailor-made autopilot system will monitor the aeroplane. The pilot will also have a vibration device fitted into their sleeves to alert them to any problems or anomalies.



This illustration shows the pilot's resting position in the Solar Impulse 2's cockpit



The pilots will have enough space to stretch and exercise to prevent blood clots

72-hour flight simulation

In preparation for the round-the-world mission, both pilots have completed 72-hour stints in a flight simulator, recreating the conditions of the Solar Impulse 2 cockpit. This enabled them to test and evaluate their nutrition plan, toilet facilities and exercise regime to prevent deep vein thrombosis (DVT). They could also try out their rest strategy, which involves using relaxation techniques for the shorter flights (24 to 36 hours) over land and taking 15 to 20-minute micro-naps for the longer stretches over oceans. Self-hypnosis and meditation techniques will also help them to maintain concentration and vigilance and help the pilots fall asleep and wake up faster.

LIFE-SAVING TECHNOLOGY

Discover amazing new medical techniques for saving lives today and in the future

Developments in technology have already enabled a great deal of significant life-saving advances in medicine. From defibrillators that can restart your heart to X-ray scanners that enable a fast and accurate diagnosis of broken bones, humans have never been so well equipped in the fight against deadly diseases, infections and illnesses.

However, there is still a lot more that can be done. New methods for improving medical practices, procedures and equipment are constantly being trialled and tested to provide much-needed solutions for doctors and patients alike, and we are already seeing some exciting new developments that could completely change the way life-threatening conditions are treated.

For example, 3D printing is already saving lives by way of made-to-measure implants designed using the patient's own anatomy, but it still has the potential to save even more lives in the near future as the possibility of printing entire human organs is quickly starting to become reality.

One area that has inspired a lot of innovation is the battle against cancer, and new tools, such as a surgical iKnife that can sniff out cancerous tissue, and a miniature microscope that can identify whether it is malignant or benign, have already been created to fight it. In the future though, the cure of cancer is likely to come on an even smaller scale. Nanorobots roughly the size of bacteria could soon be injected into our bodies to seek out diseased tissue or cells and break them down or alter them so that they are no longer harmful.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

See how a tracheal splint is 3D printed

www.howitworksdaily.com

DID YOU KNOW? *Scientists have already worked out how to bioprint vascular networks, needed to supply organs with blood*

3D PRINTING

Will printing replacement organs become a reality?

3D printing isn't just for creating car parts or toys; it is hugely beneficial for medical procedures too. Facial-reconstruction surgery is one such procedure that has been revolutionised by the 3D printer. From CT scans of a patient's head, doctors can print a 3D model of their skull and use it to design custom plates, which they can then print out and use to rebuild the patient's face. As well as enabling them to create more accurate implants, they can also print guides that help them cut and reposition the existing bone more precisely.

3D printing has also been used to save the lives of babies with severe tracheobronchomalacia, a condition that occurs when the airway walls are weak and collapse, blocking airflow to the lungs. To solve the problem, doctors at the University of Michigan used a laser-based 3D printer to create a tracheal splint. The splint was then sewn around the child's airway to act as a skeleton to aid proper growth. After two or three years, the trachea grows into a healthy state and the splint is reabsorbed by the body.

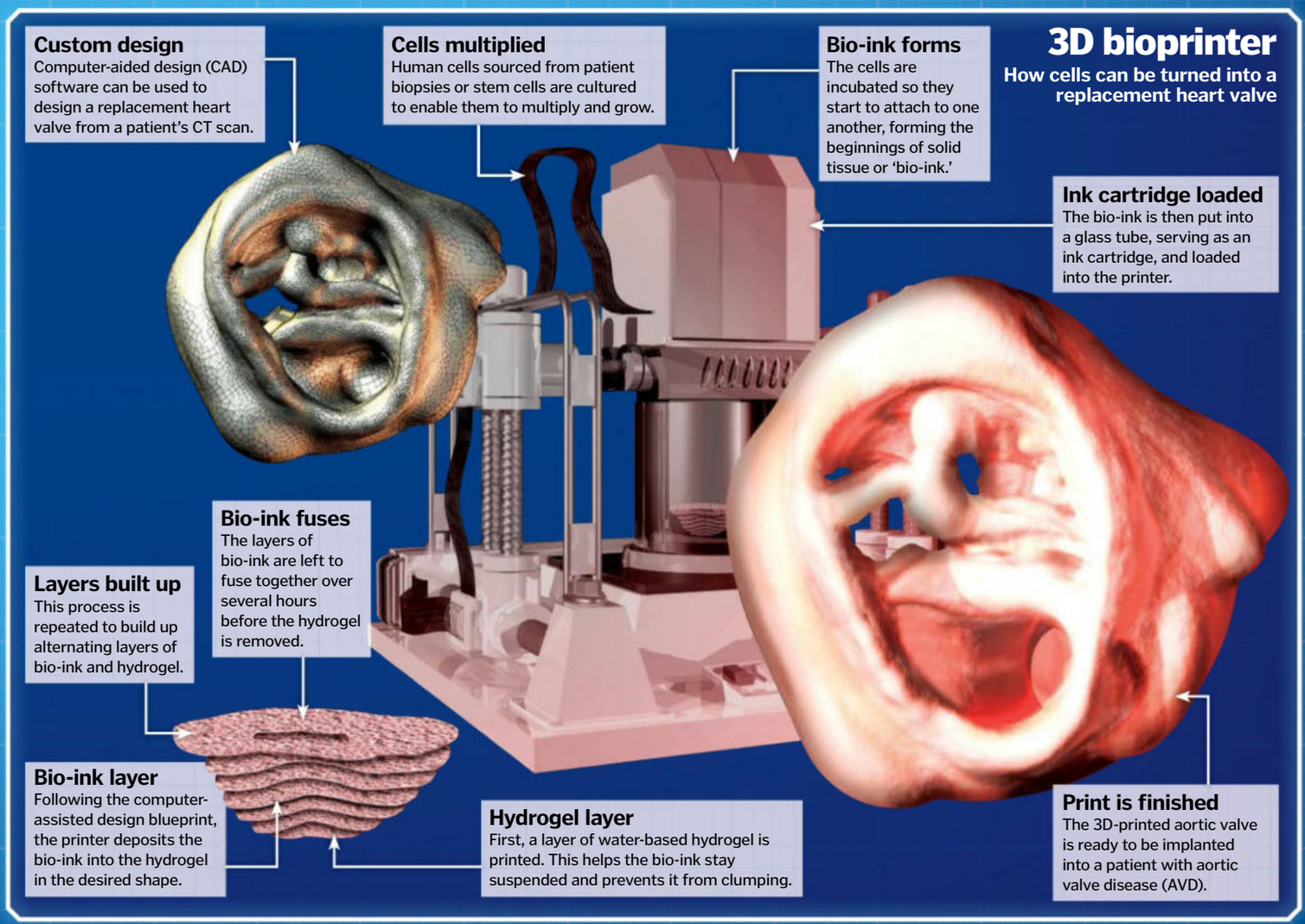
This technology is not just limited to implants, either. 3D bioprinters build up layers of human cells to create tissue. So far, this printed tissue has only been used to discover and test new drugs and investigate the causes of human disease, but scientists believe it could soon be used to print replacement parts and eventually entire organs for the thousands of patients that are waiting for transplants.

3D printing the skull of a facial-reconstruction patient in Dijon Hospital in France

The 3D-printed skull of a patient needing facial-reconstruction surgery, used to mould custom implants

3D bioprinter

How cells can be turned into a replacement heart valve



"75% of deaths from premature birth could be avoided if cheap treatments were more readily available"

INFLATABLE INCUBATOR

A low-cost invention that could give premature babies in developing countries a better chance at life

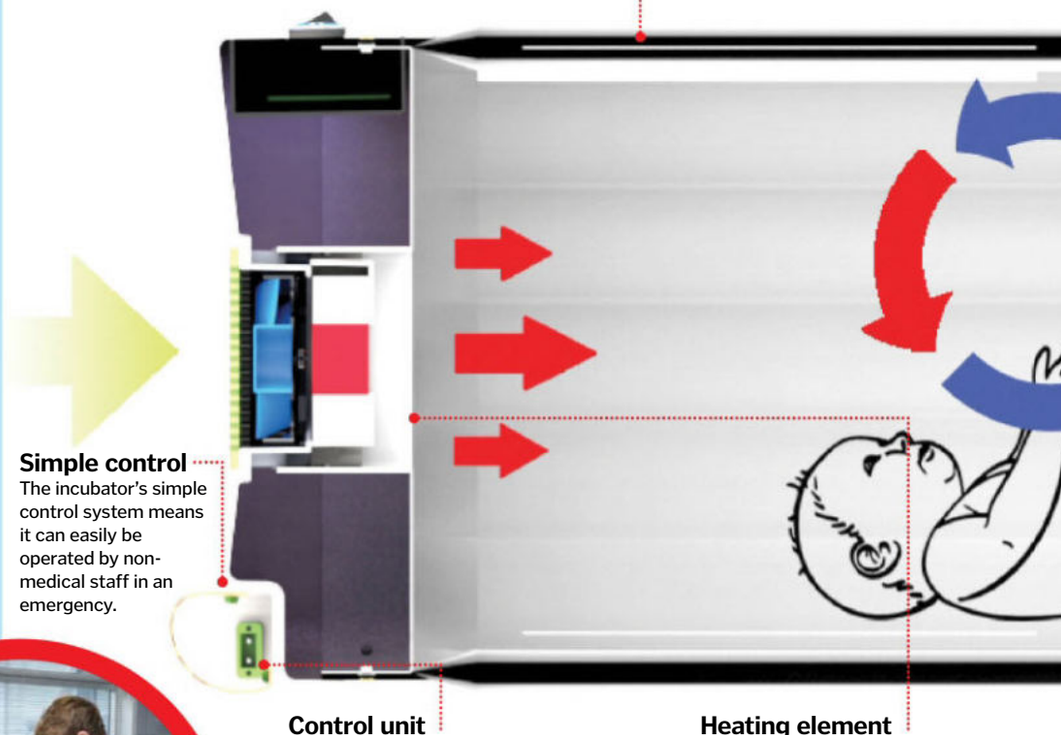
More than one in ten babies worldwide are born prematurely, but in developing countries, the equipment just isn't available to give those babies a fighting chance of survival. 75 per cent of deaths resulting from premature birth could be avoided if inexpensive treatments were more readily available, which is why a new inflatable incubator called MOM could revolutionise third-world care.

The inventor of this new machine is 23-year-old James Roberts. During the final year of his Product Design and Technology degree at Loughborough University, James was given a brief to design something that solved a problem. He chose to try and help the thousands of babies that are born too early in refugee camps across the world each year. As opposed to a normal incubator that costs upward of £30,000 ($47,000), James's portable solution costs just £250 ($390) to manufacture, test and transport to a desired location. MOM got its name because it acts as a surrogate womb for premature babies. As well as providing a stable-heat environment for the infant, it also uses humidifiers to keep their skin moist and prevent them from losing fluids. A built-in phototherapy lamp can also be used to treat jaundice, a condition that can effect any newborn, not just premature infants. It works by emitting a specific wavelength of light that lowers the bilirubin levels in the baby's blood using a process called photo-oxidation. This converts the bilirubin into a substance that can dissolve easily in water, so that the baby's liver can then break it down and remove it.

James's invention won him the 2014 James Dyson Award for design, with a £30,000 ($47,000) prize to help him develop and test his prototype further. He hopes the final version will be ready for mass production by 2017 and help save lives across the world. ▶

How MOM works

Inside the inflatable incubator prototype



Sanitary environment
Not only is the PVC ribbing a great insulator, it is also easy to wipe down and sterilise.

Simple control
The incubator's simple control system means it can easily be operated by non-medical staff in an emergency.

Control unit
The main control unit contains an Arduino computer that regulates temperature, humidification and the phototherapy lamp.

Heating element
Ceramic heating elements at each end of the incubator provide a stable heat environment that can be controlled.

Transparent panels incorporated into the incubator allow for easy access to the child inside

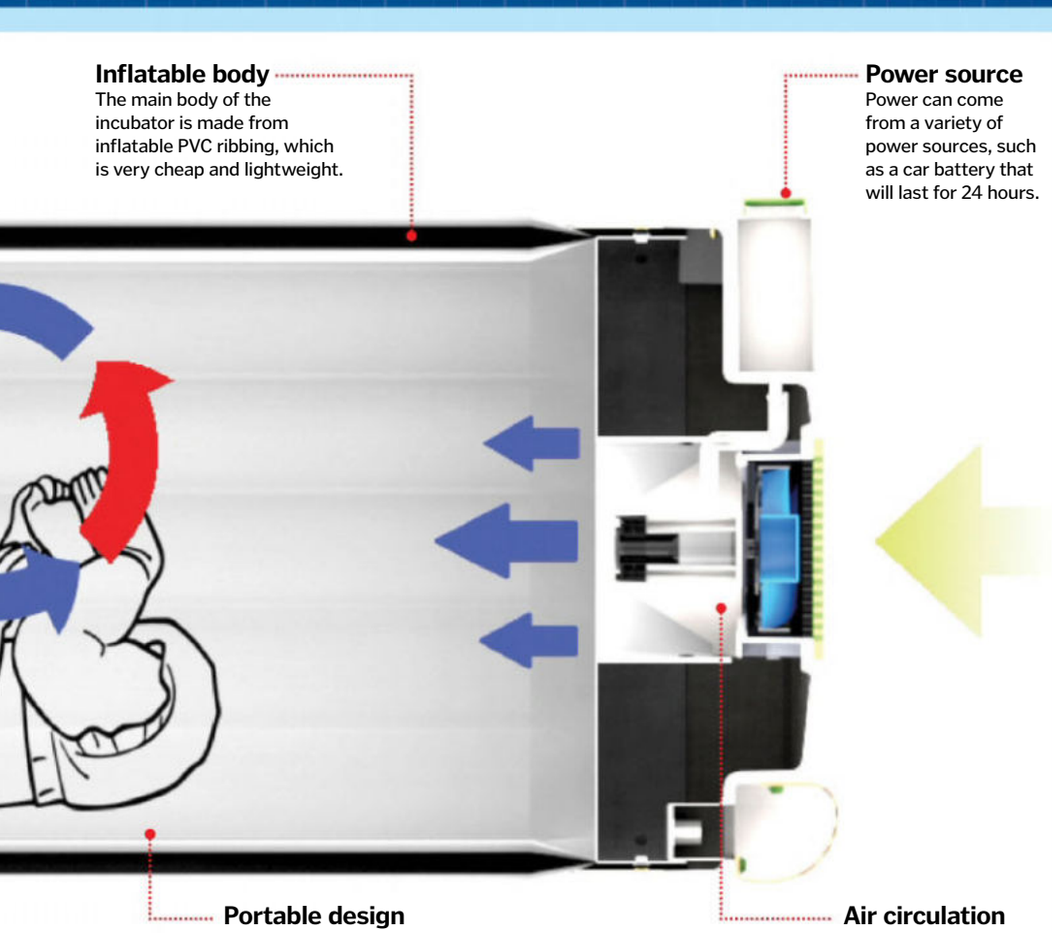
STRANGE BUT TRUE
BEDSORE STOPPER

What new invention is designed to prevent bedsores?

A Vibrating cushion B Electrical underpants C Robot nurse

Answer:
Patients confined to a bed often develop pressure ulcers or bedsores that can cause dangerous infections. However, custom undergarments called Smart-e-Pants, which deliver an electrical current to stimulate the backside muscles, are being developed to prevent them.

DID YOU KNOW? *On average, 12% of babies born in the poorest countries are premature, compared to 9% in richer countries*



One-on-one with an inventor

James Roberts reveals the story behind his creation

James's creation costs less than 1% of a standard incubator and is much easier to transport

What inspired you to design an inflatable incubator?
One night I sat down in front of my TV in my student flat and a programme about Syria came on. There was a five-minute segment in that programme showing all these premature kids that are dying just because they don't have any incubators out there. I thought there has got to be a better way of doing it and so decided to try and redesign the incubator.

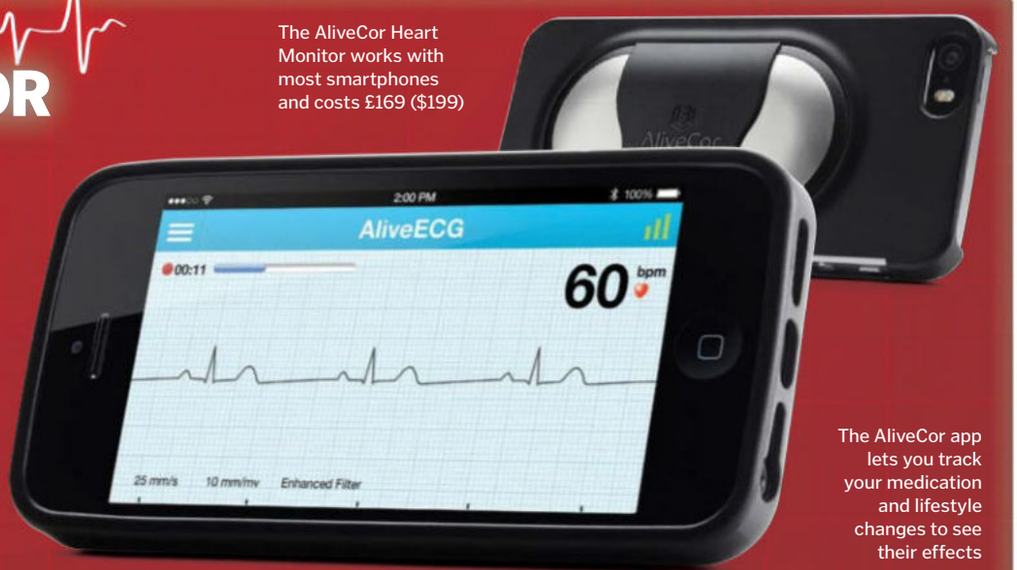
How did you start developing your idea?
I did as much internet research as I could and downloaded instruction manuals from old incubators. I also went to neonatal experts who told me what it really needed, and people who had worked in refugee camps who told me what the real problems out there were.

Did you face any problems throughout the process?
A lot of doctors I was speaking to told me I shouldn't do this; that other people hadn't been able to innovate in this field, so what makes me think I could do it? There were lots of people telling me I should do something else in my final year and not waste my time, but I thought, no, I'm going to try anyway.

SMARTPHONE HEART MONITOR

AliveCor is a heart-rate monitor that attaches to your smartphone. It records the electrical impulses that spread through the heart to make it contract by measuring your pulse through your fingers. You simply rest your fingers on the monitor and it will record this electrical activity via an electrocardiogram (ECG). After just 30 seconds, the AliveCor app will alert you if atrial fibrillation – a heart condition that causes an irregular and often abnormally fast heart rate – is detected. The innovative app also lets you keep track of and archive all your past ECGs and share them with your doctor between appointments.

The AliveCor Heart Monitor works with most smartphones and costs £169 ($199)



The AliveCor app lets you track your medication and lifestyle changes to see their effects

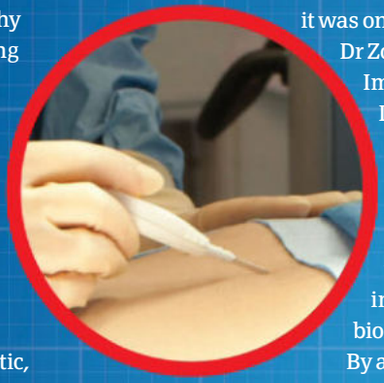
"The smoke given off as the iKnife vaporises the tissue contains important biological information"

THE CANCER-SENSING iKNIFE

The intelligent surgical knife that can instantly detect cancerous tissue

When removing tumours, it is quite common for bits of cancerous tissue to be left behind, which can then cause the tumour to regrow.

As it is usually impossible to tell which tissue is cancerous by sight, surgeons will often take out some of the healthy tissue surrounding the tumour to make sure they get it all. They can even send the removed tissue to be tested in the lab while the patient remains under general anaesthetic, but it can take up to 30 minutes to receive the results.



Even with these measures, one in five breast cancer patients who have surgery still require a second operation to fully remove the cancer. However, the iKnife could greatly improve accuracy and help them get the whole thing removed in a single operation.

The iKnife is a modified electrosurgical knife that uses heat to cut through tissue and minimise blood loss. This technology has been around since the 1920s, but it was only recently that Dr Zoltan Takats of Imperial College London realised its full potential. The smoke given off as the knife vaporises the tissue contains important biological info.

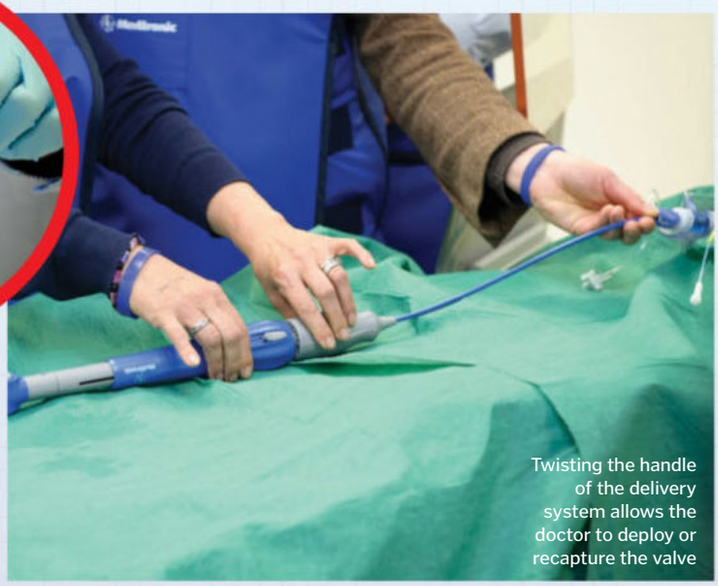
By attaching a mass spectrometer that detects the different profiles of chemicals in the smoke, the iKnife can then match its readings to a reference library of thousands of cancerous and non-cancerous tissues to determine which it is cutting in less than three seconds.

Surgeon Laura Muirhead from the Department of Surgery and Cancer at Imperial College London, using the iKnife

REPLACEMENT AORTIC VALVE

Revolutionary new system will treat aortic stenosis in the elderly

AliveCor is a heart-rate monitor that attaches to your smartphone. It records the electrical impulses that spread through the heart to make it contract by measuring your pulse through your fingers. You simply rest your fingers on the monitor and it will record this electrical activity via an electrocardiogram (ECG). After just 30 seconds, the AliveCor app will alert you if atrial fibrillation, a heart condition that causes an irregular and often abnormally fast heart rate, is detected. The app also lets you keep track of all your past ECGs and share them with your doctor between appointments.



Twisting the handle of the delivery system allows the doctor to deploy or recapture the valve

THE STATS COREVALVE

1,200 HAND-SEWN STITCHES PER COREVALVE

300k PEOPLE AFFECTED BY AS WORLDWIDE

50% DEATH RATE IN HIGH-RISK 'AS' PATIENTS

20hrs TO HAND-SEW ONE COREVALVE

65k PATIENTS TREATED WITH COREVALVE SO FAR

24-48hrs TAVI PROCEDURE RECOVERY TIME

DID YOU KNOW? *As well as detecting cancerous tissue, the iKnife can also be used to distinguish horse meat from beef*

MINIATURE MICROSCOPE

The tiny instrument that can instantly diagnose cancer

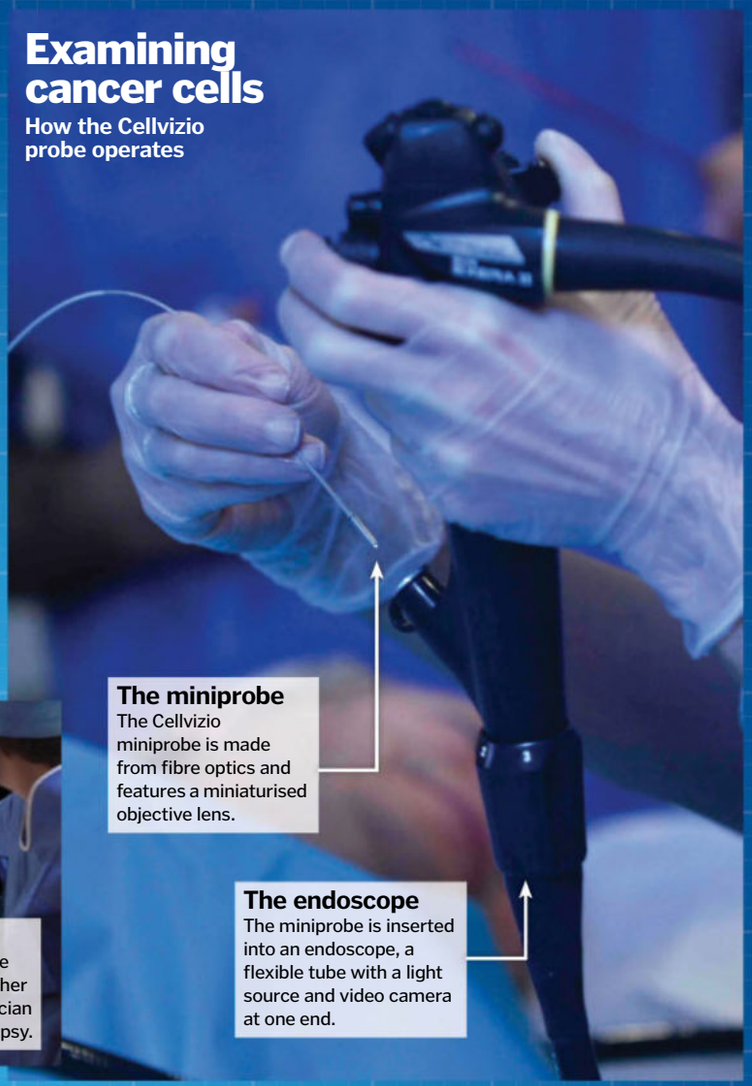
To examine potentially cancerous tissue in the human body and discover whether it is benign (non-cancerous) or malignant (cancerous), doctors would normally have to extract it and look at it under a microscope. However, a new miniature microscope that can be inserted into the patient's mouth or anus while they are conscious provides real-time results in a less invasive manner. The Cellvizio probe, developed by Mauna Kea Technologies, generates an optical biopsy that uses light to be able to see underneath the surface of tissue and examine individual cells during an endoscopy. This allows the physician to diagnose patients more quickly, so that they can begin treatment sooner and have a better chance of recovery. It's not just cancer tissue that can be examined, either, as the Cellvizio probe can also be used for deep brain imaging, to examine drug delivery and visualise infectious diseases.

Examining cancer cells

How the Cellvizio probe operates

Endoscopic images
The endoscope shows its view on a screen. When it is in position, the miniprobe makes contact with the tissue.

Cellvizio images
A microscopic image of the tissue is displayed on another screen, enabling the physician can conduct an optical biopsy.

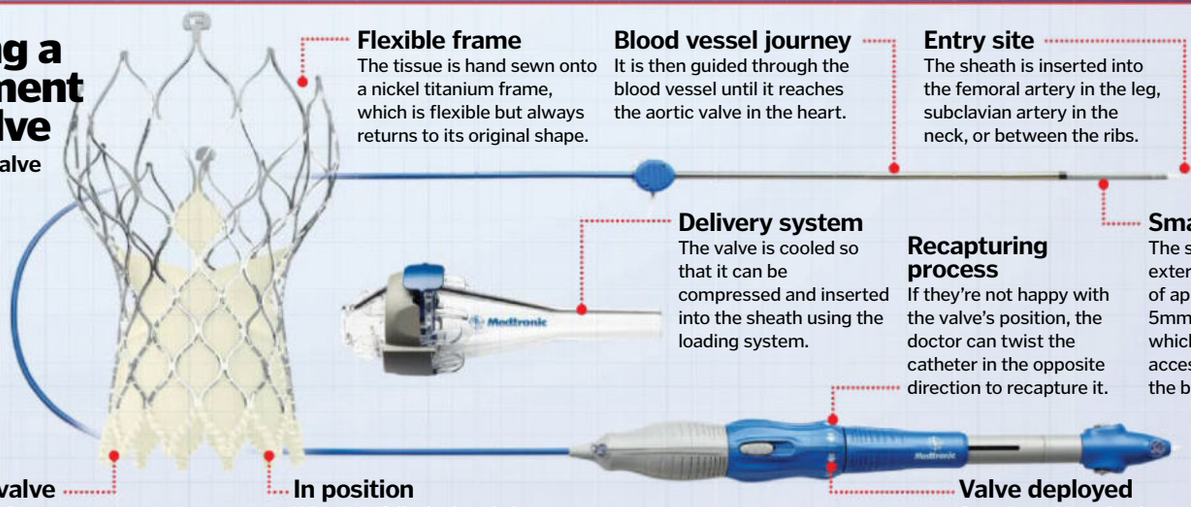


The miniprobe
The Cellvizio miniprobe is made from fibre optics and features a miniaturised objective lens.

The endoscope
The miniprobe is inserted into an endoscope, a flexible tube with a light source and video camera at one end.

Deploying a replacement heart valve

Inside the CoreValve Evolut R system



Flexible frame
The tissue is hand sewn onto a nickel titanium frame, which is flexible but always returns to its original shape.

Blood vessel journey
It is then guided through the blood vessel until it reaches the aortic valve in the heart.

Entry site
The sheath is inserted into the femoral artery in the leg, subclavian artery in the neck, or between the ribs.

Delivery system
The valve is cooled so that it can be compressed and inserted into the sheath using the loading system.

Recapturing process
If they're not happy with the valve's position, the doctor can twist the catheter in the opposite direction to recapture it.

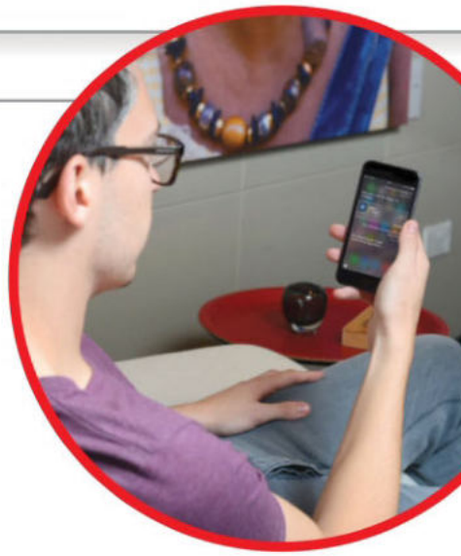
Small profile
The sheath has an external diameter of approximately 5mm (0.2in), which improves access through the blood vessel.

Transcatheter valve
The CoreValve Evolut R transcatheter valve is made from tissue taken from the pericardium of pigs.

In position
When it is fully deployed, the valve expands and pushes the damaged aortic chambers to the vessel walls.

Valve deployed
Once in position, the doctor twists the catheter to deploy the replacement valve, which slowly expands in warm temperatures.

"Apple has finally breached the four-inch [10.16-centimetre] screen-size barrier"



iPhone 6 teardown

We take a look inside the most advanced iPhone ever

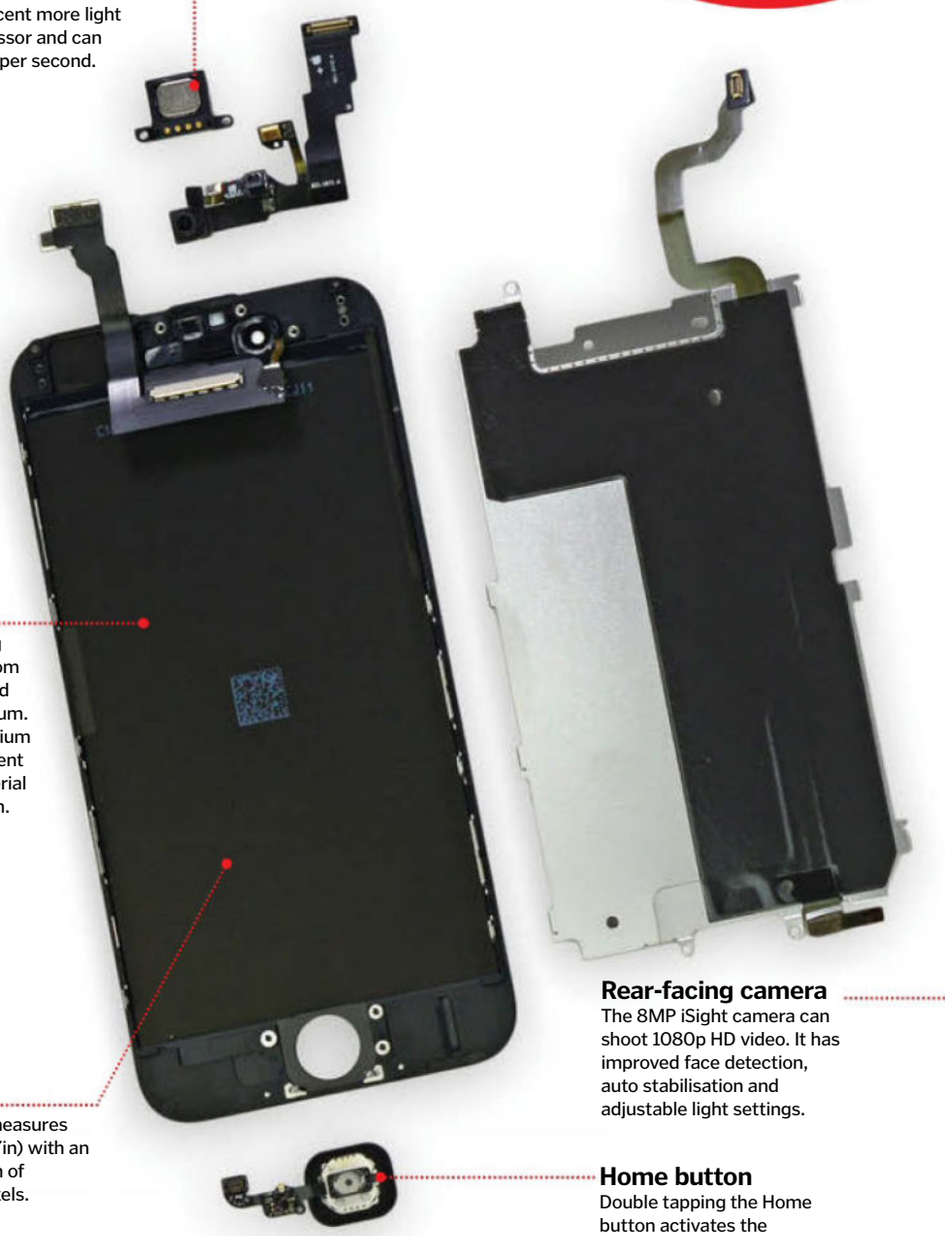
Apple's launch of the sixth generation of iPhone maintained their reputation for innovation and style due to its biggest screen ever and the revolutionary Apple Pay. The headline news has been the phones' size. Apple has finally breached the four-inch (10.16-centimetre) screen-size barrier by making the 6's screen 4.7 inches (11.9 centimetres) and the 6 Plus 5.7 inches (14 centimetres) across diagonally. This marks Apple's first foray into the phablet market.

It's not just the size that makes the screen interesting. The 6 boasts a high-definition 1334x750 display at 326 pixels per inch (ppi) resolution, while the 6 Plus houses a formidable 1920x1080 screen that runs at 401 ppi. The camera also takes a major leap forward. Users can shoot HD 1080p video at an impressive 60 frames per second, for the smoothest video experience of any iPhone video camera. The slow-motion option runs at 240 frames per second, while the front-facing camera, a staple for today's selfie-obsessed smartphone user, now lets in 81 per cent more light, making even dim surroundings a potential site for a snap.

In terms of innovation, however, the expansion of Apple Pay has to be the most exciting aspect of the new phones. Previously it would only work for items in iTunes or the App Store, but now you can use the fingerprint scanner to pay for items in a growing number of stores in the US. Apple has continued to push boundaries with this generation of iPhone, combining technology and style to create one of the most exciting phones of all time.

Inside the iPhone 6

What goes into the most powerful phone on the market?



Front-facing camera
The front-facing camera now captures 81 per cent more light than its predecessor and can snap ten photos per second.

Backing
The phone casing is constructed from stainless steel and anodised aluminium. Anodising aluminium by passing a current through the material reduces corrosion.

Screen
The screen measures 119.4mm (4.7in) with an HD resolution of 1334x750 pixels.

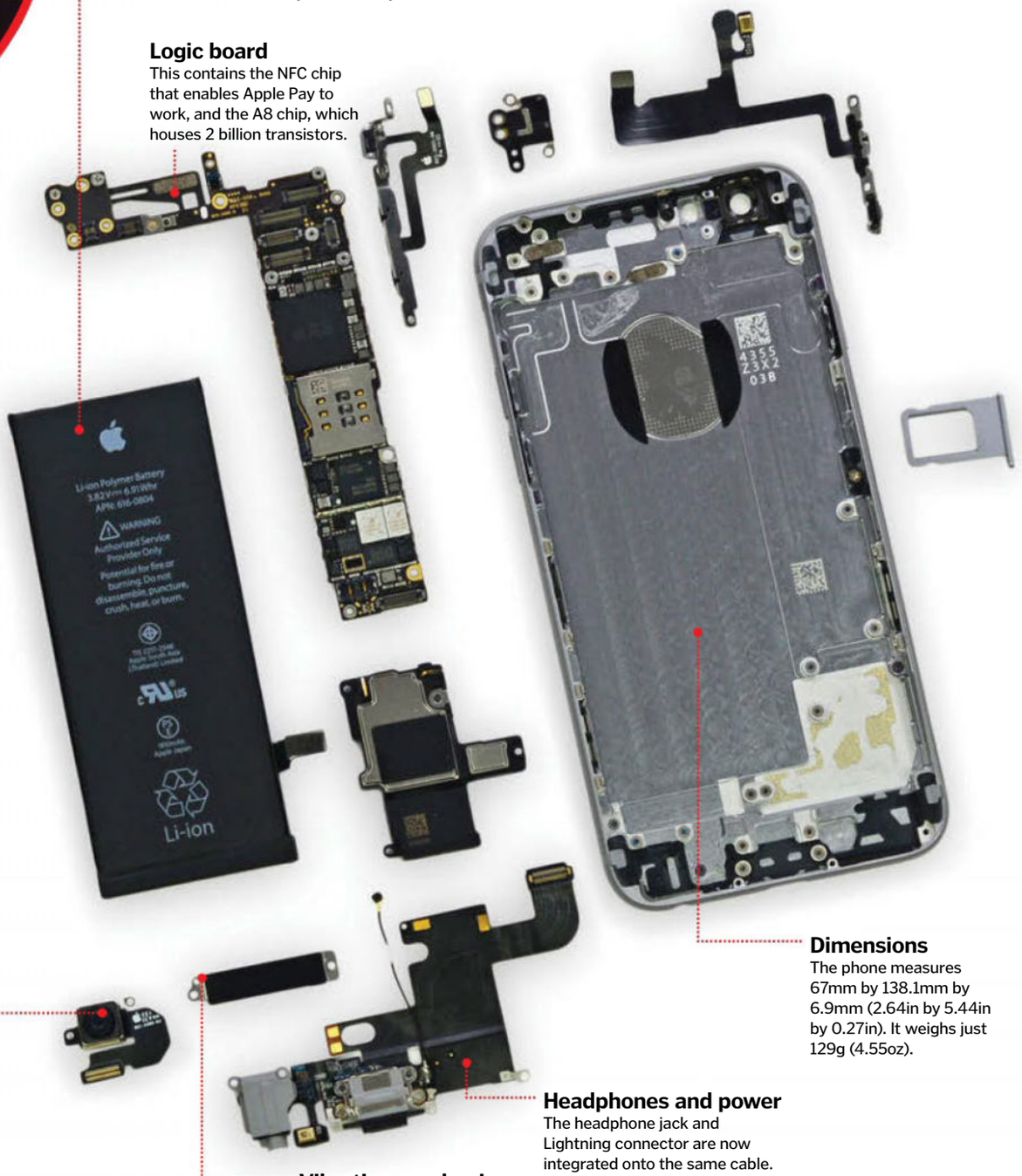
Rear-facing camera
The 8MP iSight camera can shoot 1080p HD video. It has improved face detection, auto stabilisation and adjustable light settings.

Home button
Double tapping the Home button activates the Reachability function. This draws the screen downward, closer to your thumb.

LEFT The new iPhone 6 is taller, wider and slimmer than any previous iPhone

DID YOU KNOW? *The eight generations of iPhone have sold over 500 million units between them*

"The expansion of Apple Pay has to be the most exciting aspect of the new phones"



Battery
The lithium-ion battery provides 14 hours of 3G talk time, ten hours of internet browsing and ten days on standby.

Logic board
This contains the NFC chip that enables Apple Pay to work, and the A8 chip, which houses 2 billion transistors.

Dimensions
The phone measures 67mm by 138.1mm by 6.9mm (2.64in by 5.44in by 0.27in). It weighs just 129g (4.55oz).

Headphones and power
The headphone jack and Lightning connector are now integrated onto the same cable.

Vibrating mechanism
The text/call alert uses a linear oscillating vibrator, the same as was in the 4S, for a softer vibrate function.

Apple's innovations

The three most ground-breaking additions to the iPhone through the years

1 iTunes
While the iPhone wasn't the first-ever smartphone, it certainly broke the mould in terms of design and capability. iTunes provided a platform to download and play music through your phone. Its development into the App Store in 2008 led to the app revolution of today.

2 FaceTime
At a time when video calling was still the stuff of futuristic sci-fi, Apple made it happen. A front-facing camera on the iPhone 4 enabled users to call up their friends and chat in person without actually being face-to-face.

3 Siri
The telephone was invented to talk into to other people but the iPhone 4S had people talking to their phone with the invention of Siri. The voice recognition software listens to key words, sends the request to the cloud before receiving data on anything from nearby restaurants to next week's weather.

Siri changed the way we interact with our smartphones using voice-recognition software

© iFixit; Apple

"The base layer draws moisture away from the skin in a process called capillary action"

Creating cleaner air

How air purifiers filter out dust and odours

Most air purifiers remove pollutants from the air by filtration or by ionising molecules. The filtration system uses a fan to draw air into the machine before passing it through a series of filters. These are usually foam, fibreglass or charcoal, all of which are extremely porous. This allows small air particles to pass through but catches and holds larger dust particles. Air purifiers that only let through 0.03 per cent of particles that are 0.3 micrometres or larger are given a High Efficiency Particulate Air rating from the US Department of Energy. Ionising purifiers also draw air in using a fan. Once inside, larger particles such as pollen or dust molecules pass through an electrical field called a corona discharge. This adds or removes an electron from the molecule, giving it either a positive or negative charge. The charged molecules are then attracted to one of two charged metal plates inside the purifier where they stick, allowing the clean air to pass through.

Inside Austin's HealthMate

The steps that keep your air fresh and clean

Fan
The three-speed centrifugal fan draws air into the system and expels it at 11.3m³/min (400ft³/min).

Motor
The 1.2-amp split-capacitor motor consumes 132W at maximum capacity.

Pre-filter
The pre-filter removes the largest particles of dust and hair from the air.

Panelling
The entire purifier is wrapped in a perforated steel mesh for maximum air intake.

Carbon mixture
A 6.8kg (15lb) carbon-zeolite mixture adsorbs odour-creating molecules into the crystalline structure.

HEMA filter
The filter is HEMA-approved because it removes 99.97 per cent of particles bigger than 0.3 microns.

Main filter
The second filter removes medium-sized particles such as mould and pollen.

Thermal clothing

How layered fabric can keep your warm in winter

Thermal clothing, also known as thermal underwear, is traditionally worn underneath an outfit. It's popular with those who work or exercise outdoors in cold weather, as it prevents the need to wear lots of bulky and restrictive layers. It is made from two-ply material, typically with layers of cotton, wool or synthetic fabrics such as polyester.

The base layer's purpose is to draw moisture away from the skin in a process called capillary action or wicking. This occurs where the forces of adhesion, which cause water molecules to stick to other surfaces, are greater than the forces of cohesion, which cause water molecules to stick to each other, so sweat from your skin is drawn into the narrow spaces between the clothing's fabric fibres, just like a paper towel absorbs water or a candlewick absorbs fuel. The moisture is then drawn to the outer layers of the fabric, where it can evaporate much faster and won't leave you feeling wet and cold. The outer layers also provide insulation, trapping heat so that you stay warm in cold temperatures.

Adding a thermal underlayer will keep you warm and dry on cold winter jogs

SERENA WILLIAMS, tennis

Tennis combines aerobic fitness with bursts of power, and players tend to have strong legs, backs, arms and shoulders.

TOM BRADY, American football

American football quarterbacks have to combine and balance the strength of linemen with the speed and agility of running backs.

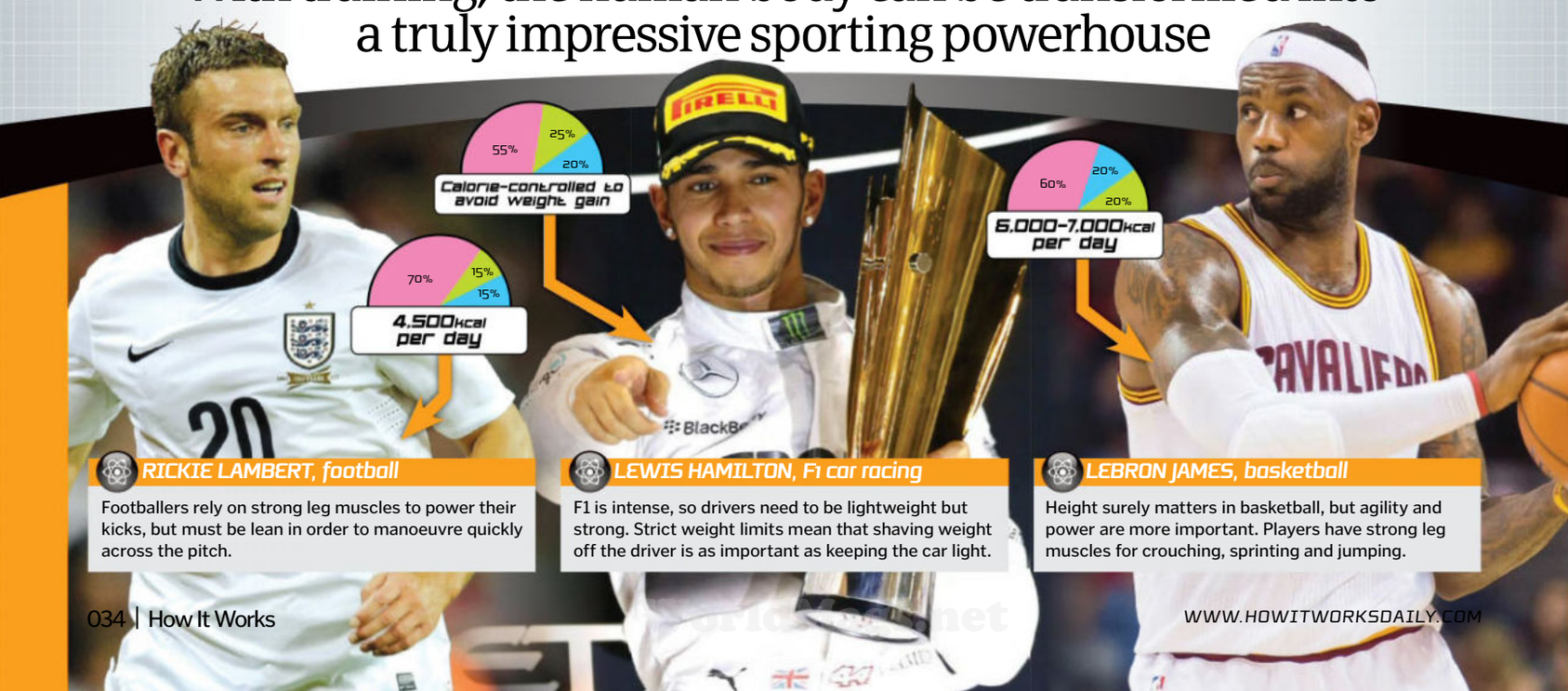
MICHAEL PHELPS, swimming

Swimmers have strong arms and well-developed core muscles, relying on their upper body for propulsion through the water.

Carbohydrate Fat Protein

SCIENCE OF SPORT

With training, the human body can be transformed into a truly impressive sporting powerhouse



RICKIE LAMBERT, football

Footballers rely on strong leg muscles to power their kicks, but must be lean in order to manoeuvre quickly across the pitch.

LEWIS HAMILTON, F1 car racing

F1 is intense, so drivers need to be lightweight but strong. Strict weight limits mean that shaving weight off the driver is as important as keeping the car light.

LEBRON JAMES, basketball

Height surely matters in basketball, but agility and power are more important. Players have strong leg muscles for crouching, sprinting and jumping.

5 TOP FACTS OLYMPIC MEDALLISTS

1 Michael Phelps, USA
US swimmer Michael Phelps is by far the most prolific Olympic medal winner, taking home 18 gold, two silver and two bronze medals between 2004 and 2012.

2 Larisa Latynina, USSR
Larisa Latynina was a phenomenal gymnast, winning nine gold, five silver and four bronze medals between 1956 and 1964. She excelled at a number of events, from the balance beam to the uneven bars.

3 Paavo Nurmi, Finland
The Finnish long-distance runner Paavo Nurmi won nine gold and three silver medals between 1920 and 1928, proving his ability both on the track, and cross country.

4 Mark Spitz, USA
Swimming legend Mark Spitz won nine gold medals, one silver and one bronze between 1968 and 1972. Seven of his gold medals were awarded in a single year.

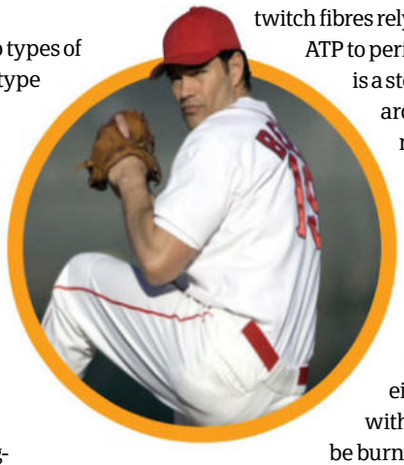
5 Carl Lewis, USA
Runner and long jumper Carl Lewis won nine gold medals and one silver in his Olympic career. He won the long jump in four consecutive Games between 1984 and 1996.

DID YOU KNOW? *Sabine Lisicki broke the record for the fastest women's tennis serve in 2014, hitting the ball at 211km/h (131mph)*

Muscles are the driving force behind sporting ability, but there is a trade-off between power and endurance. Like a cheetah, a sprinter is adapted for intense bursts of speed, but tires quickly, and like a wolf, an endurance runner can travel for a sustained period of time, but at a lower speed. With training, human athletes can choose whether to adapt their bodies for power and agility, or for endurance.

All muscles use the same energy currency to perform; a molecule called adenosine triphosphate, or ATP, generated within the muscle cells by the breakdown of glucose. The way this molecule is created and recycled differs depending on muscle type.

Muscles are composed of two types of muscle fibres, red slow-twitch (type 1) fibres, and white fast-twitch (type 2) fibres. Slow-twitch fibres specialise in burning glucose in the presence of oxygen, producing sustained activity, while fast-twitch fibres are adapted for instant power, burning fuel without oxygen for intense output over shorter periods of time.



Endurance athletes, like long-distance runners, swimmers and cross-country skiers rely on slow-twitch fibres for sustained output at lower power. In the presence of oxygen, glucose can be fully burnt, creating lots of ATP and producing carbon dioxide and water as waste. An elite endurance athlete generates over 99 per cent of their energy using oxygen.

They train by stressing their cardiovascular system, increasing the duration of exercise and performing lots of repetitions at lower power output. Training increases the volume of blood in their bodies and causes the heart to grow in size, becoming around 25 per cent larger by volume. This reduces the resting heart rate and increases the amount of blood pumped with each beat, maximising their ability to supply their muscles with oxygen.

Local improvements are also made to the muscles endurance athletes regularly use. The red colour of type 1 muscle comes from a dense capillary network and the muscle fibres themselves are packed with mitochondria, the powerhouses of the cell, which specialise in the end stages of metabolising glucose in the presence of oxygen to produce maximum ATP. Endurance athletes store more glucose in their muscles, locked away in long chains known as glycogen, and are better at diverting it through the aerobic pathway, burning it in the presence of oxygen.

In contrast, power athletes, like boxers, weightlifters and sprinters rely on fast-twitch fibres for rapid, powerful movement. Using repetitive resistance training, power athletes adapt their muscles causing the fast-twitch fibres to grow in diameter, packing more and more contractile proteins in. A good blood supply would waste valuable power-generating space within the muscle, and power muscles have fewer capillaries, hence the paler colour.

Without a constant supply of oxygen, fast-twitch fibres rely on ready-made sources of ATP to perform. Within the muscle, there is a store of ATP capable of powering around three seconds of instant movement, and once this is used up, there are rapid ways to replenish it without the need for oxygen.

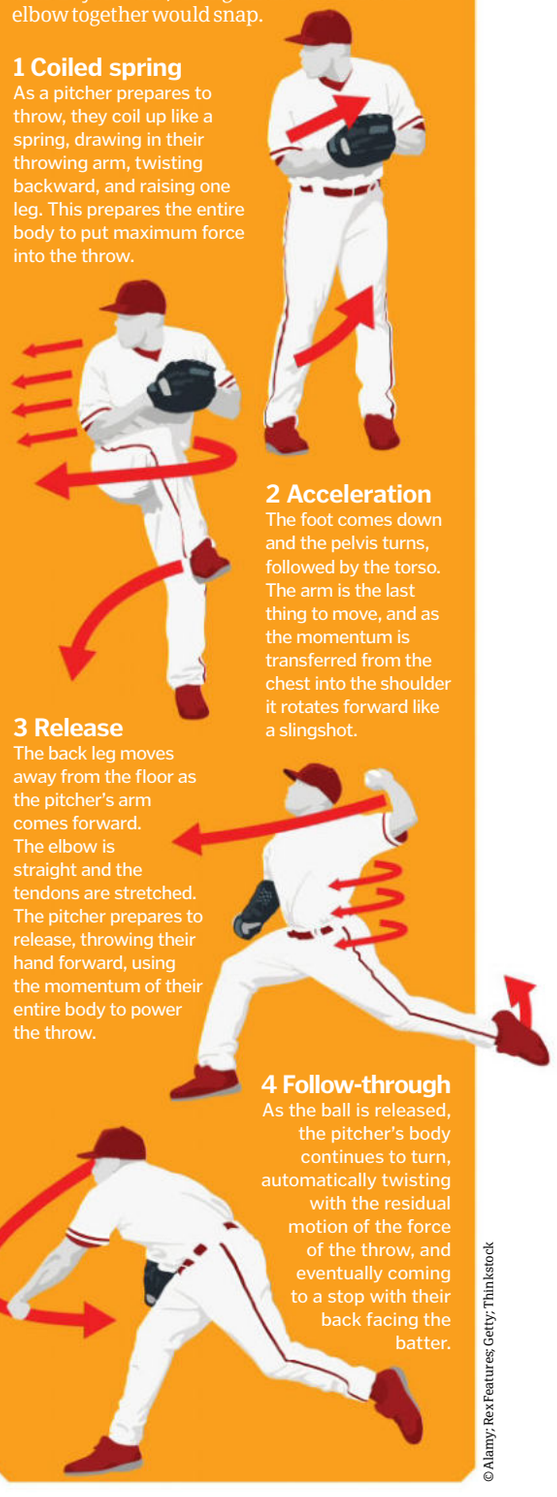
A molecule known as creatine phosphate is used to quickly restoring ATP for reuse, supplying an additional eight to ten seconds of activity without oxygen. Glucose can also be burnt anaerobically creating a smaller amount of ATP, and giving around 90 seconds of breathing-free muscle power. A men's 100-metre race can be over and done with in under ten seconds for top performers, and some athletes do not breathe at all during this time.

This type of respiration produces a high power output, but it comes at a cost, and as time goes on, waste products build up in the muscle, rapidly leading to fatigue and pain. Oxygen is ultimately required to replenish the stocks of ATP within the muscles, and power athletes are forced to stop and breathe before they continue exercising.

There is an upper limit to the sporting ability of the human body, but it seems this is yet to be reached, and science continues to improve performance. Our understanding of biology is helping to develop training and nutrition plans for athletes, while chemistry and physics are used to improve the physiology of sport, and to develop equipment used to enhance performance. World records continue to be broken, and as incredible athletes appear, their abilities are driving others to improve their game. In the year Usain Bolt smashed the world record for the men's 100 metres, the average performance of the other top sprinters improved as well, a phenomenon now known as the 'Usain Bolt Effect.'

Pitch perfect

The maximum speed a human can throw a baseball is around 160 kilometres (100 miles) per hour. This speed limit is capped by basic human anatomy. A pitcher moves his or her shoulder at incredible speeds, putting an estimated 100 Newton-metres (74 pound-feet) of torque on the arm. Beyond this, the ligament that holds the elbow together would snap.



1 Coiled spring
As a pitcher prepares to throw, they coil up like a spring, drawing in their throwing arm, twisting backward, and raising one leg. This prepares the entire body to put maximum force into the throw.

2 Acceleration
The foot comes down and the pelvis turns, followed by the torso. The arm is the last thing to move, and as the momentum is transferred from the chest into the shoulder it rotates forward like a slingshot.

3 Release
The back leg moves away from the floor as the pitcher's arm comes forward. The elbow is straight and the tendons are stretched. The pitcher prepares to release, throwing their hand forward, using the momentum of their entire body to power the throw.

4 Follow-through
As the ball is released, the pitcher's body continues to turn, automatically twisting with the residual motion of the force of the throw, and eventually coming to a stop with their back facing the batter.

"As the muscles work, waste products like carbon dioxide, potassium and acids start to build up"

MECHANICS OF MOVEMENT

Discover how your heart and lungs keep your power-hungry muscles moving

At rest, the skeletal muscles receive around 20 per cent of the blood pumped with every heartbeat, but during exercise, their oxygen requirement rockets. They are given priority over almost all other tissues, and up to 80 per cent of the cardiac output is diverted to supply their increasing demands. Adrenaline from the adrenal glands above the kidneys and noradrenaline released from nerve endings increases the heart rate, and causes the arteries to constrict, diverting blood flow away from other areas of the body, like the digestive organs.

As the muscles work, waste products like carbon dioxide, potassium and acids start to build up, and the tissue becomes hypoxic as the oxygen is used up. These strong signals override the constriction of blood vessels, causing the local blood vessels within the working muscles to dilate. At the same time, the acidic by-products change the shape of the pigment haemoglobin, and as the red blood cells pass they drop their oxygen in the place where it is needed most.

The heart is pumping so quickly that the blood spends much less time in the capillaries of the lungs, so the time for gas exchange to take place is shorter. However, when increased carbon dioxide in the blood reaches the brain, the rate and depth of breathing increases, and raised blood pressure forces extra alveoli and capillaries open, creating an even greater surface area for gas exchange, and ensuring that carbon dioxide is swapped for oxygen as the blood passes.

As the muscles continue to contract and relax, they squeeze the veins in the legs and arms, helping to force blood back toward the heart. This in turn maximises the amount of blood pumped with each beat.

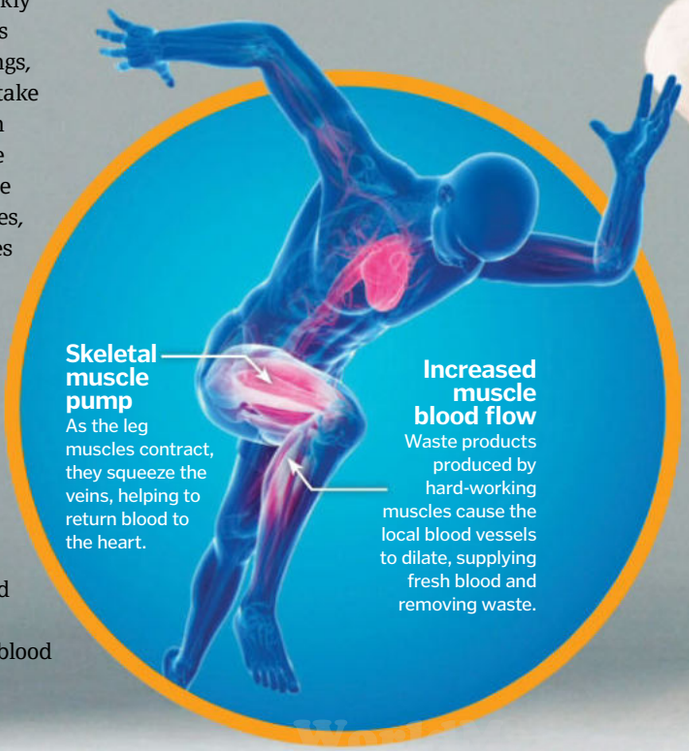
Balance and momentum
The legs, arms and torso work together to balance the body and to drive the runner forward.

Nervous control
The brain responds to higher carbon dioxide levels in the blood by increasing the rate and depth of breathing.

Open airways
The airways widen and increased blood pressure forces extra capillaries in the lungs to open, maximising the surface area for gas exchange.

Biomechanics of running

To keep your muscles moving, the body needs to make compromises as you run

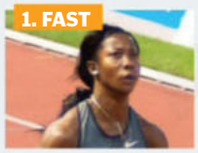


Skeletal muscle pump
As the leg muscles contract, they squeeze the veins, helping to return blood to the heart.

Increased muscle blood flow
Waste products produced by hard-working muscles cause the local blood vessels to dilate, supplying fresh blood and removing waste.

Sugar release
Glucose is released from stores in the liver to supply the muscles.

HEAD 2 HEAD
FAST WOMEN



Shelly-Ann Fraser-Pryce
The current 100-metre women's world champion is Jamaican Shelly-Ann Fraser-Pryce, who set a time of 10.75 seconds at the Olympic Games in 2012.

Carmelita 'The Jet' Jeter
Carmelita Jeter achieved the second-fastest recorded 100-metre sprint, covering the distance in an incredible 10.64 seconds.

Florence Griffith-Joyner
US athlete Florence Griffith-Joyner set the world record for the women's 100-metre sprint in 1988 with a time of 10.49 seconds.

DID YOU KNOW? *The world marathon record is two hours, two minutes and 57 seconds, set in 2014 by Dennis Kimetto*

SPORTS INJURIES

The most common sporting injuries affect the muscles, bones, ligaments, tendons and joints, and can be caused by a number of things, from physical accident to overtraining and poor technique. The first line of treatment is to stop exercising and give the tissue time to repair and recover.

If the damage is severe, involving a broken bone or a tear, medical intervention is necessary to ensure proper healing, but for most routine injuries, at-home medical remedies are sufficient. The acronym RICE – for rest, ice, compression and elevation – is often used to remind people of the procedure in case of an injury. Rest to avoid further damage to the area, ice for pain relief, and compression and elevation to limit blood flow and bring down swelling.

Non-steroidal anti-inflammatory drugs, like ibuprofen, can also help to reduce swelling and relieve pain, and physiotherapy can aid in restoring muscles and joints to normal function after the injury has healed. Gentle exercise is important to stretch and strengthen the area after the initial healing process.

Digestion halted
The blood vessels constrict, diverting blood flow away from nonessential organs like the stomach, intestines, and kidneys.

Mythbusters!

1 Sports drinks improve your performance

Many sports drinks claim to replace minerals lost through sweating, but the concentrations of ions in the drinks are so low that they make little difference. You can make an isotonic drink at home using 800ml (28fl oz) of water, 200ml (7fl oz) of sugary squash and a pinch of salt, but eating a healthy snack, such as pretzels or a banana, before or after exercising is more effective.

2 Caffeine boosts endurance

In laboratory tests on elite athletes, caffeine equivalent to around one mug of coffee has been shown to improve athletic performance, but these results have not been repeated in the field, and the mechanism is unknown. The effects have not been tested on the general population because muscle fatigue kicks in before the benefits would be seen.

3 Special running shoes prevent injury

Many shops offer services to monitor your gait and prescribe shoes that support the foot and ankle depending on how your feet move as you run, but recent studies show that these specialist shoes make no difference to injury rates. Technique is much more important, and experts recommend that you choose comfortable, well-fitting shoes for exercise.

"Contrary to popular belief, lactate acts to neutralise the acid, not to create it"

Cool down
Blood vessels in the skin widen, allowing excess heat to escape to the environment.

Lactate
During strenuous exercise, lactate builds up as a buffer to reduce free acid produced in the muscles.

Continued metabolism
Lactate is converted to carbon dioxide and water, which then leave the body through the breath.

Stretching
There is no hard evidence that stretching helps to minimise the risk of injury or relieve the pain of post-exercise muscle pain.

Oxygen debt
Oxygen is required to break down the lactate produced during intense exercise, so the athlete continues to breathe heavily.

MUSCLE RECOVERY

When exercise ends, the muscles need time to rest and repair

During intense and prolonged exercise, your muscles demand more oxygen than your heart and lungs can supply, and they start to burn. This familiar sensation is often blamed on lactate.

Lactate has a bad reputation and is widely criticised for being the cause of lactic acidosis; a painful build-up of acid within the muscles leading to fatigue and muscle soreness, but in reality this idea is a myth. The acid that causes muscles to burn is not caused by lactate, but is a normal side effect of energy use. Lactate actually acts to neutralise the acid, not to create it.

During intense exercise, muscles demand huge quantities of the energy molecule ATP; each time a molecule is split, a hydrogen ion (H+) is released. If the muscle is receiving enough oxygen, this acid is used as part of the normal metabolic processes of the cell, but if not, this acid starts to build up, causing the muscles to burn. As glucose is broken down to create more ATP, two molecules of pyruvate are generated. This pyruvate can hold on to two H+ molecules, mopping up the acid to become lactate, which itself can be broken down to produce more energy.

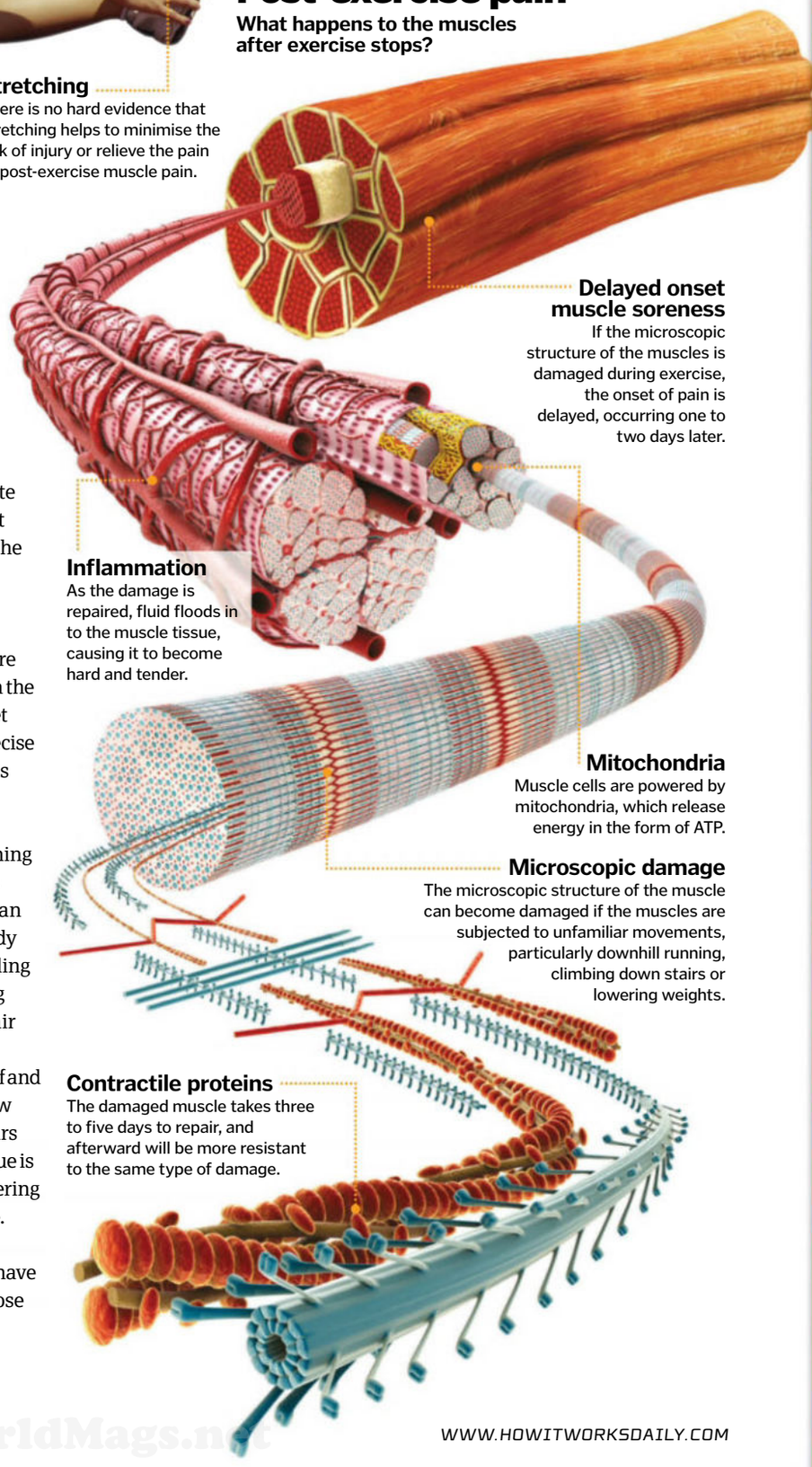
The more an endurance athlete trains, the better they become at using up the H+ and the slower the lactate builds, meaning elite athletes can exercise for longer before feeling the burn.

Several days after exercise there may be a different kind of pain in the muscles, known as delayed onset muscle soreness (DOMS). The precise mechanism is not known, but it is thought that during strenuous exercise, particularly involving movements that combine stretching with muscle contraction (such as running downhill) micro-tears can occur within the muscle. The body responds with inflammation, filling the muscle with fluid, and taking immune cells with it to help repair the damage. This inflammation causes the muscle to become stiff and tender. The pain only occurs a few days after exercise and disappears within a week as the muscle tissue is strengthened and repaired, lowering the likelihood of similar damage.

Interestingly, very few randomised controlled studies have been done on stretching, but those that have suggest that it neither reduces pain after exercise, nor reduces the risk of injury.

Post-exercise pain

What happens to the muscles after exercise stops?



Delayed onset muscle soreness
If the microscopic structure of the muscles is damaged during exercise, the onset of pain is delayed, occurring one to two days later.

Inflammation
As the damage is repaired, fluid floods in to the muscle tissue, causing it to become hard and tender.

Mitochondria
Muscle cells are powered by mitochondria, which release energy in the form of ATP.

Microscopic damage
The microscopic structure of the muscle can become damaged if the muscles are subjected to unfamiliar movements, particularly downhill running, climbing down stairs or lowering weights.

Contractile proteins
The damaged muscle takes three to five days to repair, and afterward will be more resistant to the same type of damage.

2.45 METRES

HIGH JUMP WORLD RECORD

The men's high jump world record was set in 1993 by Cuban athlete Javier Sotomayor, who leapt over a bar a staggering 2.45m (8.04ft) off the ground.

DID YOU KNOW? *The resting heart rate of an elite athlete is ca 40 beats per minute, compared to 70 for an untrained person*

DIFFERENT STROKES

Swimming success is all about balancing forward propulsion through the water while minimising drag

Freestyle – also known as the front crawl – is the fastest type of swimming stroke, combining powerful arm movements with a flutter kick, which keeps the legs up and minimises the frontal surface area exposed to the oncoming water. Swimmers use their hands and forearms as paddles to pull themselves through the water, keeping the head in line with the straight body and facing down toward the floor of the pool.

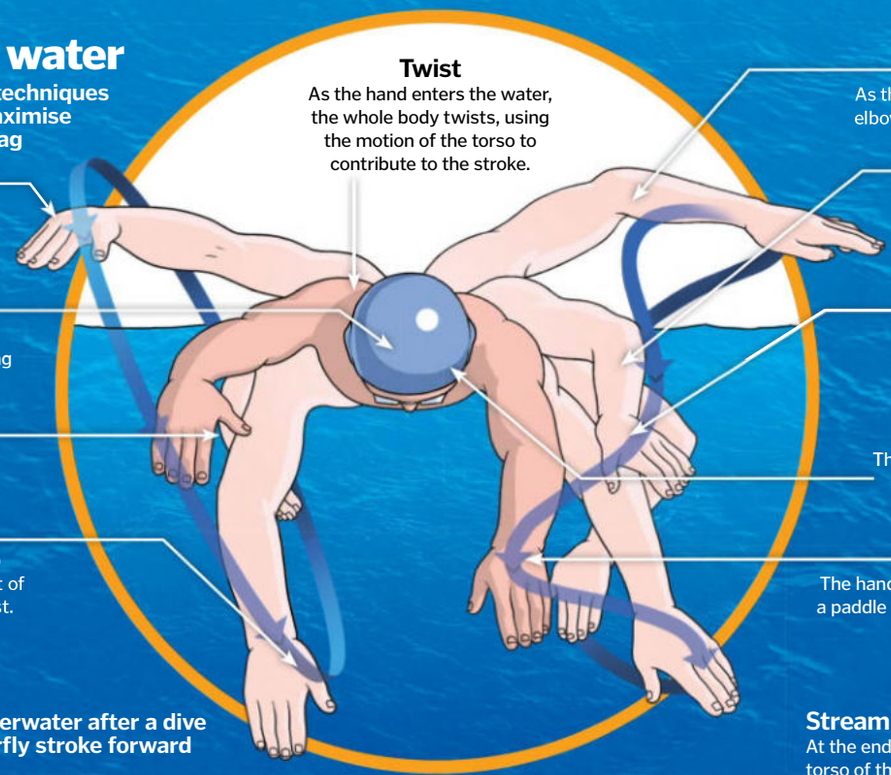
With each stroke, freestyle swimmers rotate from side to side, using the core muscles in their backs and shoulders to contribute to each movement. This allows them to efficiently slice through the water, and also enables them to reach farther with each arm movement, pulling more water back with their hands.

The technique of the swimmer is only part of the story, and the achievements of elite athletes are aided by technology in their clothes, and in the pool itself. Pools are designed to minimise waves as the swimmers move, and the lane markers help to prevent turbulence spreading from one swimmer to the next. The water level is kept as high as possible to prevent waves reflecting off the edges.

High-tech materials in swimwear help to decrease drag, and full-body suits compress the body into a cylinder, preventing wobbling and improving the hydrodynamic profile of the athletes, allowing their bodies to move more easily through the water. These led to many world records being broken in 2008 and 2009, but the suits are now banned in competitive swimming, helping to ensure achievements are based purely on athletic skill.

Gliding through water

See how two different stroke techniques – deep catch and skulling – maximise water caught and minimise drag



Reach
The swimmer reaches forward, maximising the amount of water that can be pushed back with each stroke.

Side breaths
When the swimmer needs to breathe, they turn their head to the side, keeping the body balanced and streamlined.

Fingers first
The fingertips enter the water first, slicing through the water.

Deep catch
In this stroke, the hand is pushed deep into the water, maximising the amount of fluid caught and producing more thrust.

Twist
As the hand enters the water, the whole body twists, using the motion of the torso to contribute to the stroke.

Elbow up
As the arm comes out of the water, the elbow comes out first minimising drag.

S-shape
The sculling stroke reduces both lift and drag, but can allow endurance swimmers to go for longer without tiring.

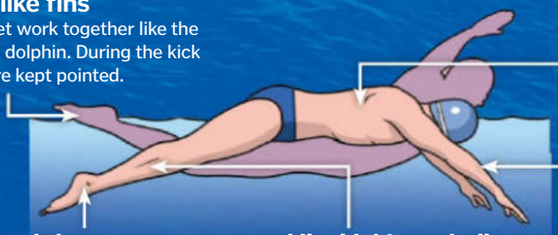
Sculling
With a sculling stroke, the elbow is bent and the arm moves in an S-shape through the water.

Head straight and down
The head, legs and body are held in a straight line, keeping the swimmer streamlined and minimising drag.

Paddle
The hand and forearm are used together as a paddle to pull the body through the water.

Dolphin kick

This powerful kick is used underwater after a dive or turn, and to drive the butterfly stroke forward



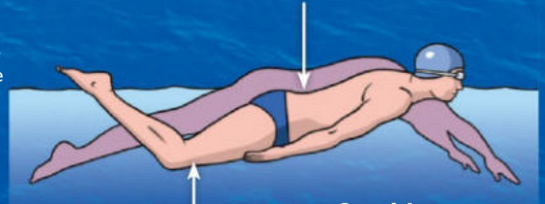
Feet like fins
The feet work together like the fin of a dolphin. During the kick they are kept pointed.

Stiff core
The upper body is tense and the hips are controlled – most of the movement is in the legs.

Forward thrust
As the legs straighten, water is forced down and back by the feet, pushing the swimmer forward and upward.

Like kicking a ball
The power comes from the hips and knees, which whip the lower legs forward.

Power from the arms
There are two kicks per butterfly stroke, helping the momentum as the arms enter the water, and again as they leave.



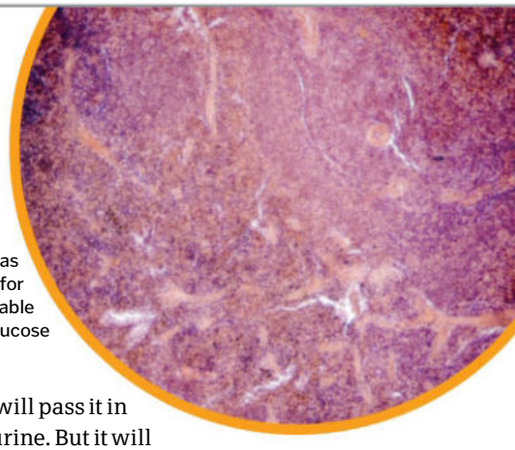
Streamlined shape
At the end of the stroke, the arms and torso of the swimmer form a straight line, and the head is tucked in.

Quadriceps power
The power of the kick comes from the muscles in the thighs, which snap the legs straight.

"High levels of glucose in your blood can be damaging and even fatal"

The importance of insulin

The hormone that controls your blood sugar levels



The pancreas produces insulin for the body to be able to absorb glucose

When you eat, your digestive system breaks down the food and passes its nutrients into your bloodstream. These nutrients include glucose (sugar), but high levels of glucose in your blood can be damaging and even fatal. To keep these levels low, your pancreas produces insulin to help cells absorb the glucose so they can use it as energy. As well as helping fat and muscle cells to absorb glucose, insulin helps your liver hold on to any excess glucose in your body so that it can release it when it is needed, such as between meals, when exercising or if your blood sugar level is too low.

If your body fails to produce any or enough insulin, or if your cells become resistant to the hormone, this results in a condition known as diabetes. It increases your blood sugar level and you can develop hyperglycaemia. To try to get rid of the excess glucose in your blood, your body will pass it in your urine. But it will also take more water with it, leading to an increase in frequency and volume of urination and an increase in thirst. If left untreated, it can lead to a condition called diabetic ketoacidosis, where the body breaks down fats and proteins for energy instead of sugars, resulting in a build-up of ketones (acids) in the blood. This can lead to unconsciousness and even death.

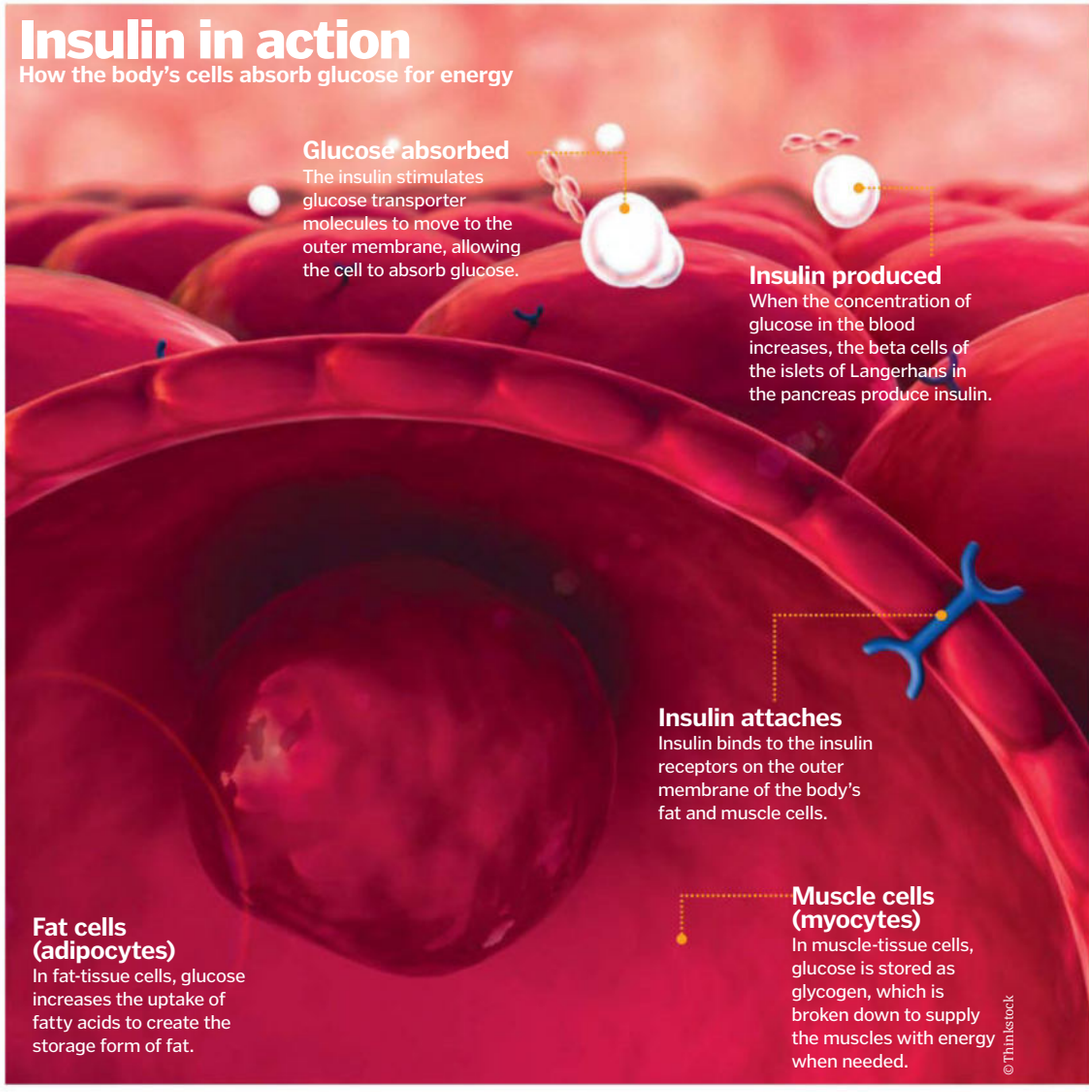
Injecting insulin

There are two main types of diabetes. Type 1 occurs when the pancreas does not produce any insulin, and Type 2 occurs when the pancreas doesn't produce enough insulin or if the body's cells do not react to the insulin being produced. Although there is no cure for diabetes, people with Type 1 can control the systems by regularly injecting themselves with insulin or using a pump that constantly sends insulin into their blood at a rate they control. They also need to monitor their blood sugar levels by pricking their finger and placing a drop of blood on the testing strip of a blood glucose meter. Doing this before and after meals will help them adjust their insulin injections and diet accordingly. People with Type 2 diabetes can control their symptoms by eating a healthy, balanced diet and exercising more regularly, but may need injections if their condition progresses.

Insulin can be injected into the abdomen, upper arm, upper buttocks or outer thigh

Insulin in action

How the body's cells absorb glucose for energy



5 TOP FACTS
SMALL BUT MIGHTY

Bacteria in the body
1 There are approximately ten times as many bacterial cells as human cells in the human body, most of which are found in the lining of the digestive system.

Older than humans
2 Bacteria are among the oldest life forms on Earth. They have been around for far longer than we have, and scientists have even found bacterium fossils.

Taking shape
3 Bacteria come in many shapes, and can be spherical or look like rods, corkscrews, spirals or commas. These single cells can join up as pairs, chains or clusters.

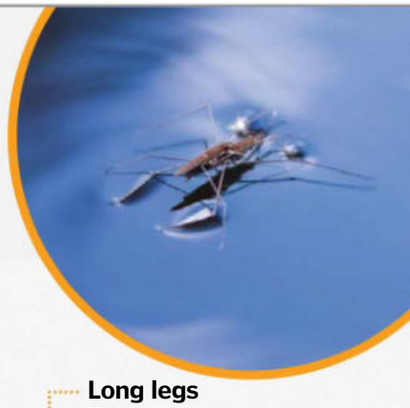
Good bacteria
4 We couldn't survive without some of them. Good bacteria strengthen our immune and digestive systems and help our environment, like in sewage systems and oil spills.

Bad bacteria
5 Some bad bacteria thrive in dirty environments, others on and in certain foods. They can go on to cause infectious diseases that can be fatal.

DID YOU KNOW? *Water striders also use the surface of water to communicate to each other by sending ripples across it*

Walking on water

Revealed: An insect's secret to staying afloat



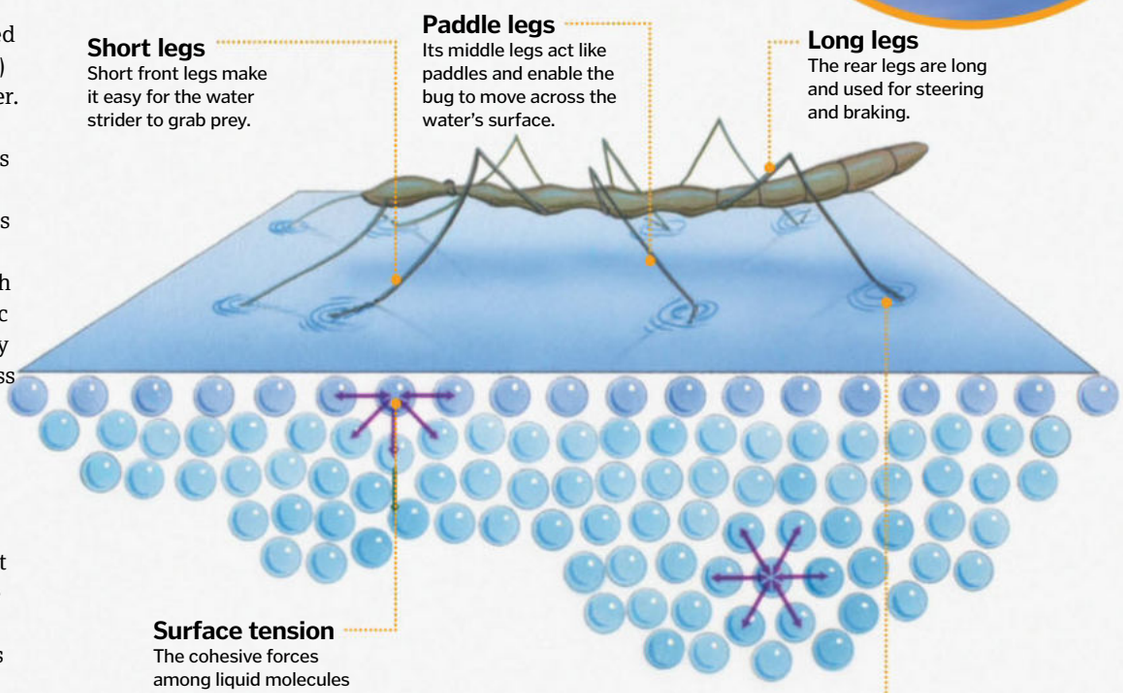
Skating across the surface of a pond, the water strider achieves the somewhat miraculous act of walking on water thanks to its incredible anatomy and the power of physics. This little insect is classed as a true bug (a member of the Gerridae family) and lives on or around the surface of freshwater. It occasionally dips below the surface to see what lies beneath, but the water strider spends most of its time living up to its name.

Despite the bug being denser than water, it is able to float or skate across the surface of it without breaking through. Its feet bend in such a way that the water deforms, much like elastic film. The insect's legs and underside of its body are covered in tiny hairs, which aid this process further by trapping air bubbles between them and the water's surface to help them float.

If this isn't impressive enough, the water strider's front, middle and rear legs have their own important functions that contribute toward its survival on water. Its middle legs act as paddles, making movement possible, while its long rear legs enable it to steer and even brake as it glides across the water. Its front legs are also short enough to grab prey as it passes delectable insects – living or dead – along the way. Thankfully, the speed at which the water strider can move means it stands a chance against its own predators.

Anatomy of a water strider

How does the water strider use its body to walk on water?



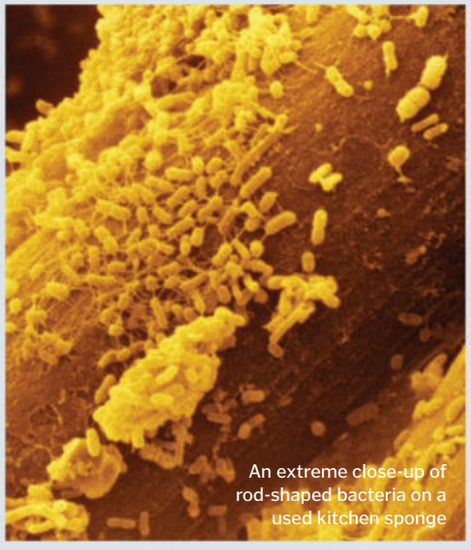
Bacteria explained

Find out how these microorganisms can survive anything

These single-celled microorganisms are often referred to as microbes due to their ability to spread diseases. Unlike other organisms, they do not have a membrane-bound nucleus, but rather a single DNA loop that stores genetic information.

Although just a few micrometres in length and therefore too small to see with the naked eye, bacteria certainly make up for their size and seemingly simple cell structure by being rather complex little creatures. First, they can survive absolutely anywhere. Although they have different survival requirements depending on their habitats, bacteria adapt to their environment. From boiling hot springs to sub-zero temperatures; whether deep below the Earth's surface or high up in its atmosphere, as long as they have nutrients to grow and reproduce, they can withstand conditions that no human ever could.

Bacteria reproduce when the bacterium splits into two identical daughter cells. Known as binary fission, this process can occur at an incredible rate. This can be dangerous when the bacterium is pathogenic and is why diseases can spread so quickly.


An extreme close-up of rod-shaped bacteria on a used kitchen sponge

How aerosols turn liquid into gas

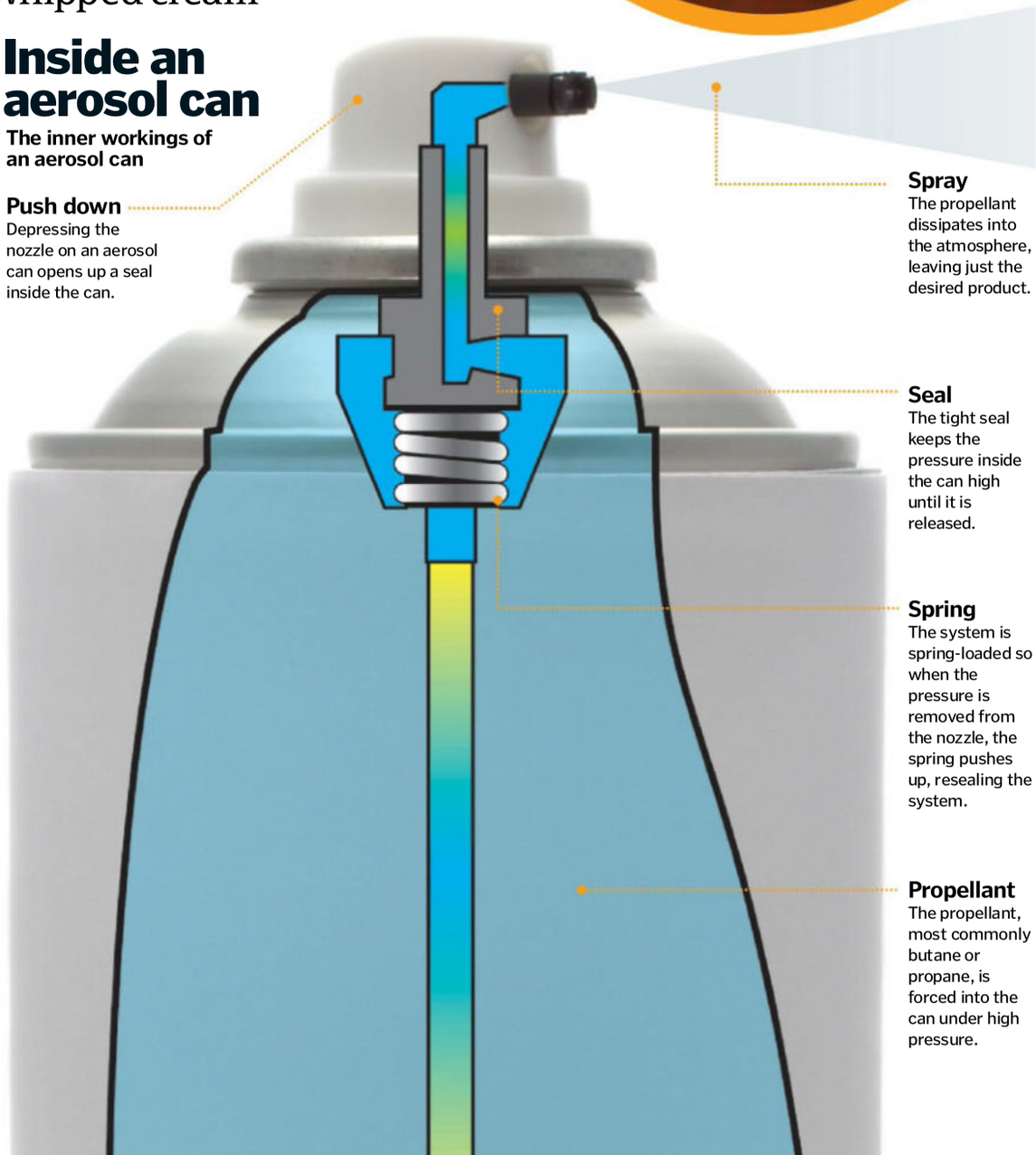
The science behind how aerosols spray everything from deodorant to whipped cream

Aerosol sprays can be used for everything from spray painting to topping cakes

Aerosol cans are highly pressurised cylinders that use a gaseous propellant to expel their contents. The more common system is the liquefied gas system. Liquid product gets poured into the can before the propellant is forced in through the nozzle at somewhere between two and eight times its normal atmospheric pressure. Aerosol propellant was originally made from chlorofluorocarbons (CFCs), but as they are hazardous to the ozone layer, liquefied propane and butane are generally used now. The propellant has a boiling point lower than room temperature, but the intense pressure it is under stops it from boiling. Depressing the nozzle opens up an airtight seal, releasing the pressure. As the pressure is reduced the propellant boils and breaks up the product, forming a gas mixture of propellant and product. This gets pushed out through the newly created gap and out of the nozzle in the form of a fine spray. The pressure is reduced as the volume of product and propellant decreases, which is why each spray is slightly less forceful than the previous one. Thicker substances like shaving cream work in the same way but when the propellant is forced out it forms bubbles inside the product instead of dissipating, creating a foamy result. The exception to this is aerosol cans in which food, such as whipped cream, is stored. Propane and butane are not safe to ingest, so liquefied nitrous oxide, otherwise known as laughing gas, is used instead. Aerosol cans are traditionally made from a thin sheet of steel or aluminium wrapped in rust-resistant tin. The cylinder is wrapped around a curved steel base and welded shut at the end to ensure the high-pressure gas cannot escape.

Inside an aerosol can

The inner workings of an aerosol can



Push down
Depressing the nozzle on an aerosol can opens up a seal inside the can.

Spray
The propellant dissipates into the atmosphere, leaving just the desired product.

Seal
The tight seal keeps the pressure inside the can high until it is released.

Spring
The system is spring-loaded so when the pressure is removed from the nozzle, the spring pushes up, resealing the system.

Propellant
The propellant, most commonly butane or propane, is forced into the can under high pressure.

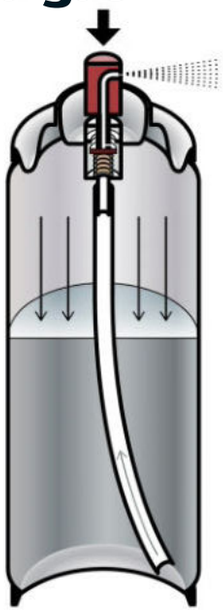
"As the pressure is released the propellant boils and breaks up the product"

What is an aerosol?

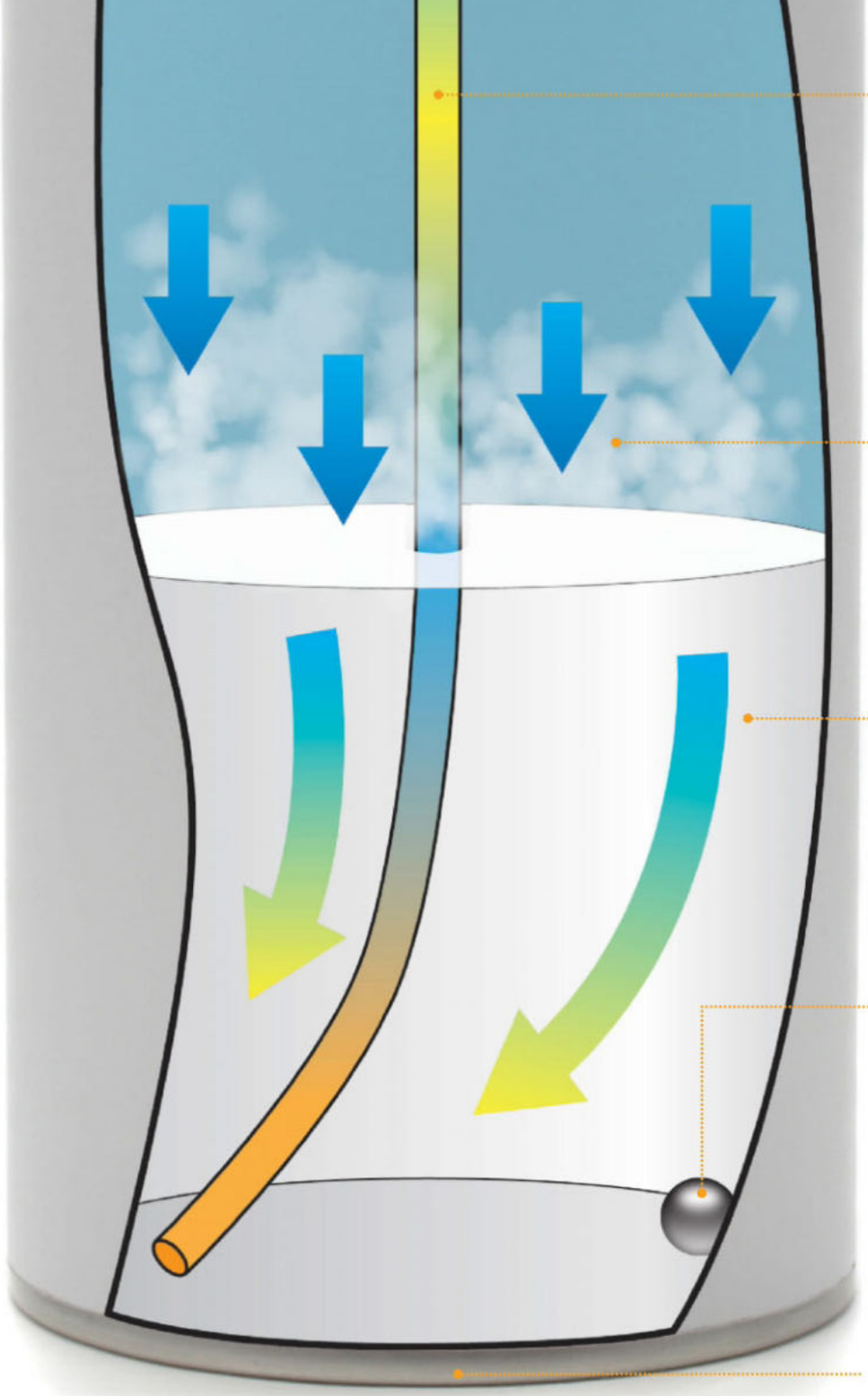
Aerosol is actually a very general term for a mist of solid or liquid particles that are dispersed in a gas. As well as the deodorant that comes out of a can, there are plenty of other aerosols we encounter in our daily lives. Steam from a kettle is an aerosol because it contains droplets of water vapour. The smoke from candles is another kind of aerosol as the melted wax and soot particles are suspended within the surrounding air.

Compressed gas

The other common method of creating an aerosol spray is the compressed gas system. This system begins in a similar manner to the liquefied gas system as the liquid product gets poured into the can. It gets sealed shut and the gaseous propellant is pumped into it via the nozzle. As with the liquefied gas system, the propellant is highly pressurised, but here it doesn't mix with the liquid product. It sits on top of the product instead, squashing it to the bottom of the can and up a tube that ends just below the nozzle. When the nozzle is depressed the airtight seal is opened and the downward force of the propellant pushes the product out of the gap. The small nozzle atomises the liquid product, breaking it up into tiny droplets that form a misty spray.



The compressed air system pushes down on the product without mixing



Boiling
When the seal is opened, the propellant boils, atomising the product and pushing it out of the nozzle in the form of a spray.

Mix-up
Where they meet, the liquefied propellant merges with the liquid product to create a mixture.

Product
The product you want to dispense gets poured into the can in liquid form and gets forced downward by the gas.

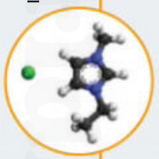
Ball bearing
Some aerosol cans contain a ball bearing that rattles around when shaken, mixing up the propellant and product.

Base
The base of most aerosol cans is curved inward to counteract the pressure exerted inside the can.

KEY DATES
HISTORY OF THE AEROSOL CAN

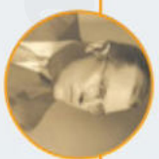
1790 The first pressurised cans containing liquid come from France, used to hold carbonated drinks.

1899 The first aerosol is patented by Helbling and Pertsch, for methyl and ethyl chloride.



1927 The first aerosol can is patented. Norwegian Erik Rotheim combines a pressurised can and valve system to dispense a product.

1943 Improved by Dr Lyle Goodhue, aerosol cans prove their worth during WWII by holding mosquito-killing spray.



1987 The Montreal Protocol bans the use of CFCs in aerosols after their destructive effect on the ozone layer is discovered.

DID YOU KNOW? *Thomas Midgley Jr, the inventor of CFCs present in early aerosol cans, also invented poisonous leaded petrol*

"Each enzyme contains a crack called an active site into which a molecule can fit"

How micellar cleansing water works

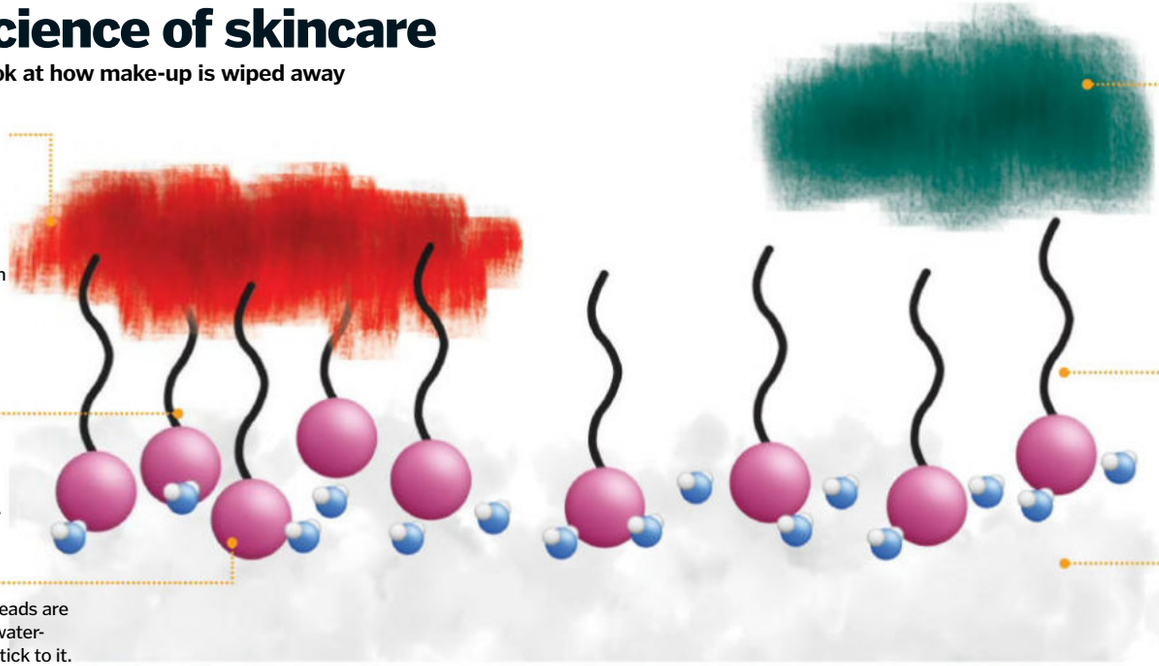
The chemistry behind the gentlest make-up remover on the market

Micellar cleanser takes advantage of water-loving and water-hating molecules to remove make-up

Micellar cleanser has us marvelling at how this water-like solution removes make-up so easily. A micelle is a made up of molecules that have water-loving (hydrophilic) heads and water-hating (hydrophobic) tails. They form as little spheres, with the heads facing outward and the tails pointing inward. When you pour the micellar solution on the cotton pad, the hydrophilic heads are attracted to the cotton, leaving the hydrophobic tails pointing outward to attract oil and make-up. The tails form a ring around the oil, pulling it gently away from your skin and onto the wipe like a magnet.

The science of skincare

A close-up look at how make-up is wiped away



Strong bond
As the bond between the water and hydrophilic head is strong, the micelles stay with the cotton pad, pulling the make-up away.

Cluster
A group of micelles form a cluster around the oil molecules.

Head
The hydrophilic heads are attracted to the water-soaked pad and stick to it.

Oil
The tail is attracted to the oily make-up and wraps itself around the molecules.

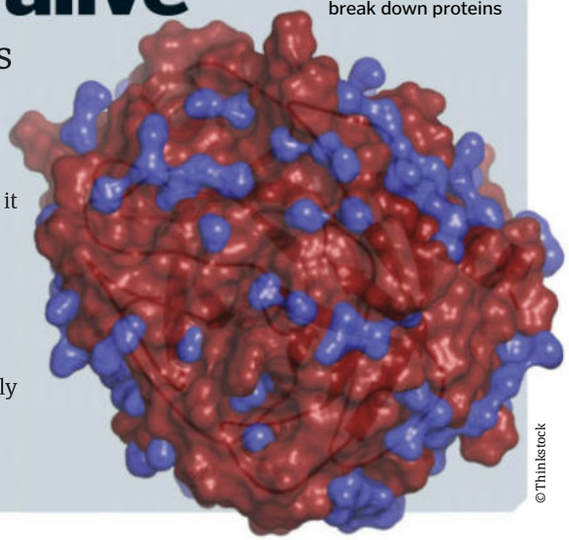
Tail
The hydrophobic tails hate water so point away from the pad.

Absorption
Cotton soaks up the cleanser, which is a solution of water and the micelle molecules.

How enzymes keep you alive

The proteins that speed up your body's chemical reactions

Enzymes such as trypsin work to help break down proteins

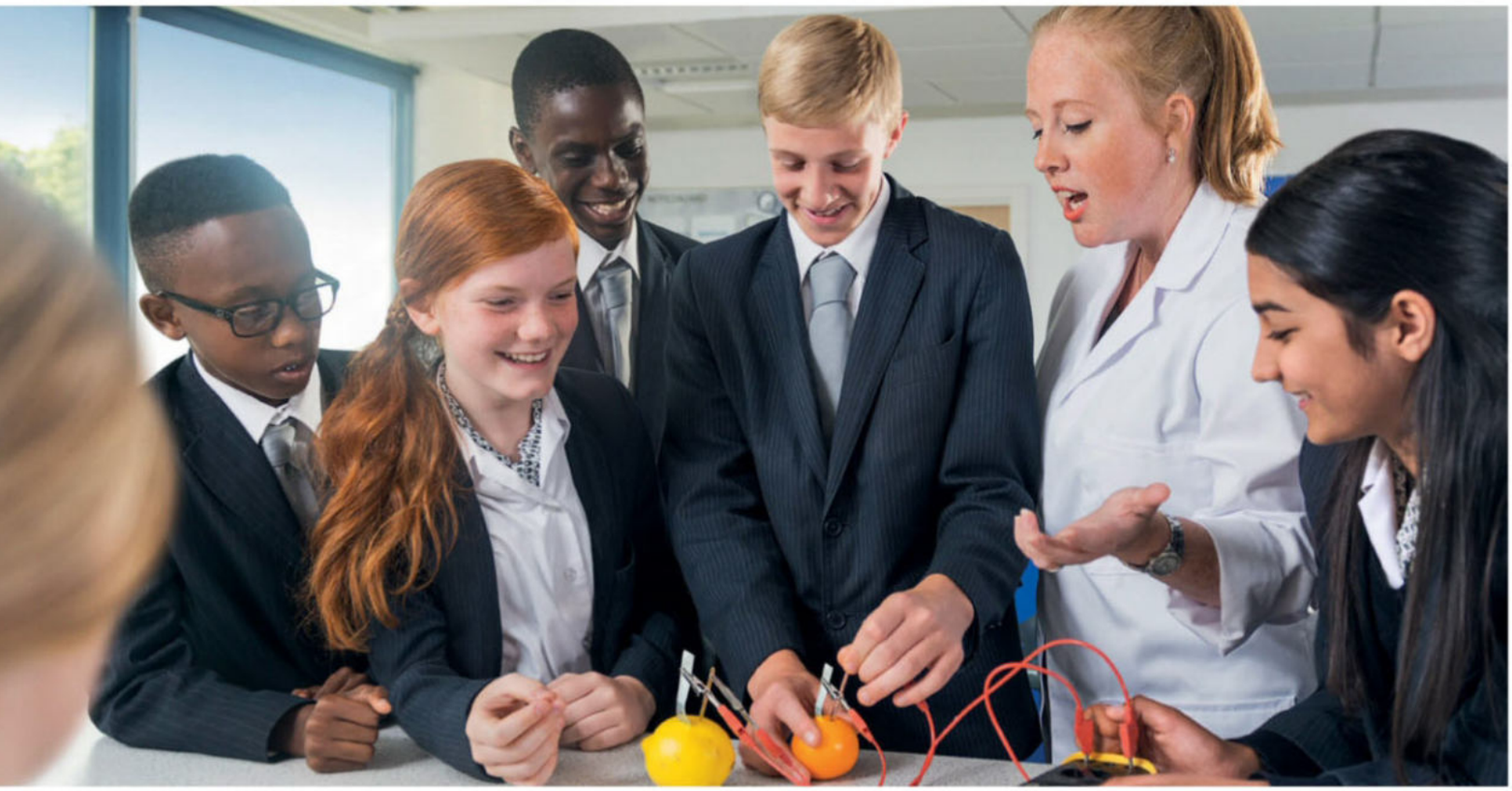


Enzymes increase the speed of reactions inside cells by lowering the energy-activation requirement for molecular reactions. Molecules need to react with each other to reproduce, but our bodies provide neither the heat nor the pressure required for these reactions.

Each cell contains thousands of enzymes, which are amino acid strings rolled up into a ball called a globular protein. Each enzyme contains a gap called an active site into which a molecule can fit. Once inside the crack, the molecule – which becomes known as a substrate – undergoes a reaction such as dividing or merging with another molecule without having to expel energy in a collision with another molecule. The enzyme releases it and floats on within the cell's cytoplasm. The molecule and active site need to match up perfectly in order for the sped-up reaction to take place. For example, a lactose molecule would fit into a lactase enzyme's active site, but not that of a maltase enzyme. Interestingly enough, enzymes don't get used up in the process, so they can theoretically continue to speed up reactions indefinitely.

Receive £25k tax-free to train as a physics teacher

and give students the power to reach their potential.



Did your love of physics begin with a great physics teacher? Imagine inspiring that same enthusiasm for the subject in the next generation. As a physics graduate, you could receive a £25k* tax-free bursary or a £25k* tax-free scholarship provided by the Institute of Physics, as well as support and advice from our Premier Plus service. You'll also get the satisfaction that comes from helping children reach their true potential.

Applications are now open.
Search **get into teaching** to find out more.

TEACHING
YOUR FUTURE | THEIR FUTURE

IOP Institute of Physics

Department for Education

*Conditions apply. Visit education.gov.uk/teachconditions

LIFE AND DEATH IN ANCIENT EGYPT

From their ingenious inventions to their gruesome burial rituals, we explore the mysterious past of the Egyptians

9
The age of Tutankhamun when he became pharaoh

Sphinxes, mummies, curses – the mysterious world of Ancient Egypt has had people gripped for centuries. Though its armies could never compete with those of Ancient Rome, and its thinkers failed to influence modern philosophy in the same way the Ancient Greeks did, there is something about the Egyptians that makes them seem far more tangible than their ancient counterparts. We can read their texts, touch their treasures, and even visit their tombs. However, despite those impressive monuments, what perhaps fascinates us most about the Ancient Egyptians is the strange and sacred way they lived their lives, and the even stranger way they dealt with death. From the gruesome mummification process to the backbreaking construction of pyramids, the rituals of this superstitious civilisation seem a million miles away from the world we know today.

How It Works transports you back in time to a land where the gods were many and the squeamish were few, and unveils some of the mysteries surrounding this magnificent kingdom. Find out about the advancements the Egyptians made to medicine and agriculture, and how they built the indestructible temples and tombs that have stood for millennia. There is so much to learn about Ancient Egypt, and we just keep digging up more.

1. BIG

Red Pyramid
Built by Pharaoh Sneferu, this was the world's first successful attempt at constructing a true pyramid, and is 104m (341ft) high.

2. BIGGER

Pyramid of Khafre
This is the second-biggest pyramid at Giza and originally rose to a height of 143.5m (471ft), but is now 7m (23ft) shorter.

3. BIGGEST

Great Pyramid of Giza
Built for Pharaoh Khufu, it originally stood at 146.5m (481ft) tall and is made of more than 2 million limestone blocks.

DID YOU KNOW? *If a mummy's bandages were unwrapped, they could stretch for 1.6km (1mi)!*

What did the Egyptians do for us?

Can you think of something the Egyptians invented? Probably not. Though most people know the Romans invented central heating and the Greeks held the first Olympics, we don't really think of the Egyptians as great innovators – rather as magicians and murderers! But in fact, there are many inventions we still use today that started off life in the desert. From things as simple as eye make-up and breath mints, to far more complex systems like the written language and calendars, the world would be a very different place if it weren't for the Ancient Egyptians.

Egyptian art and architecture also had a big influence on future generations across the globe. When painting and sculpting people, the Egyptians used a grid to help them determine the proportions. Greek artists who travelled to the ancient kingdom were inspired by their technical approach to art, and went on to use the Egyptian grid in their classical pieces. Equally, Egyptian-style obelisks and pyramids can now be seen the world over in both ancient and modern architecture, and copycat jewellery even makes an appearance on fashion runways.

130+
The number of pyramids discovered in Egypt so far

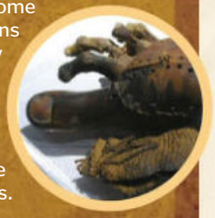
However, it is probably their contributions to science and language that have altered the course of history in the most dramatic way. How they managed to perform the calculations and puppeteer the building of such impressive structures as the pyramids without the use of modern technology is something that has baffled historians for centuries. Here we take a closer look at Egypt's greatest accomplishments...

Mathematics

It is believed the Ancient Egyptians were the first to use a base ten numeral system. By this we mean that they had different symbols for one unit, ten, one hundred, and so on up to one million. Although many early civilisations had a measuring system of some kind, the Egyptian 'cubit' was the standard linear measurement in the ancient world. Measurements like these were based on body parts, with one cubit equalling the length from the elbow to the middle fingertip. It was vitally important for the Egyptians to have a good understanding of mathematics in order to build their magnificent pyramids and temples.

Medicine

The use of medicine in Ancient Egypt is one of the first on record. Though their cures and practices changed little over the course of 3,000 years, at the time they were some of the most advanced in existence. This included simple operations, the first dental practices and the setting of broken bones. They were also the first to conduct significant research into the workings of the human body. However, a lot of their remedies included the use of magic, and some of their potions could be very strange indeed – like honey and human brains to cure eye infections.



Paper & written language

Though the Chinese have been credited with the invention of paper in the 2nd century BCE, the Ancient Egyptians were documenting their lives millennia before. This is thanks to their invention of papyrus sheets – a type of parchment made from papyrus plants that grew along the banks of the River Nile. They used a system of pictograms called hieroglyphs in order to write things down. While the use of drawings to tell stories was nothing new, the Egyptians added alphabet-like characters that stood for certain sounds to their writing system, allowing them to write out names and abstract ideas.

Agriculture

The first ploughs can be traced back to the Sumerians in 4000 BCE, but these were incredibly ineffective and relied on pure elbow grease for operation. This all changed when in 2000 BCE, the Ancient Egyptians hooked up their ploughs to oxen instead. This revolutionised farming for both Egyptians and people overseas, and animal power is still used today. They are also regarded as being the first civilisation to successfully control the flow of water. They dug irrigation canals to take water from the Nile when it flooded and hold it back for use during the dry season.

Building the pyramids

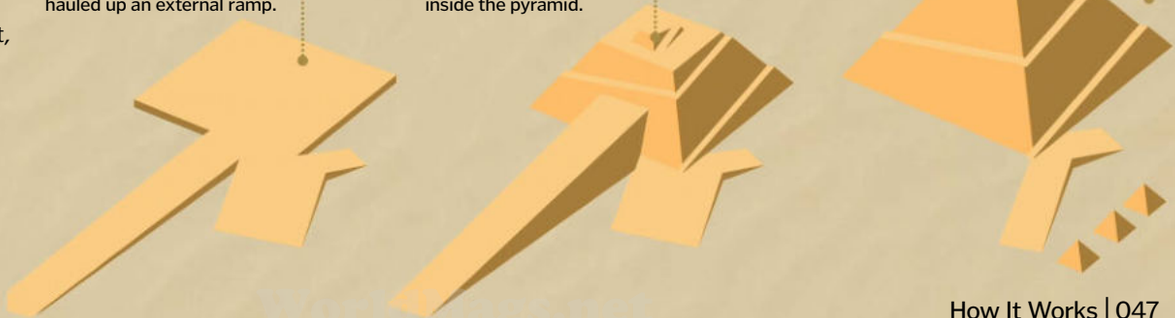
Some clever calculations and a whole lot of manpower were needed to build these world wonders

Egyptologists have been trying to solve the mystery of the pyramids' construction for centuries. The theories of how such a primitive civilisation could build such giant, durable and geometrically sound structures are vast, ranging from early cranes to extra-terrestrials! However, one of the most recent theories to emerge, known as the 'internal ramp theory', could provide the answer...

Year five
The theory suggests that for the bottom third of the pyramid, the blocks were hauled up an external ramp.

Year 16
As the bottom part was being built, another ramp was being built inside the pyramid.

Year 20
The blocks for the top two-thirds were dragged up the internal ramp, while the external ramp was slowly dismantled to provide extra building material.



"The river allowed transport and communication from one end of the kingdom to the other"

Egyptian life

Most of what we read about the Ancient Egyptians revolves around death, from their gruesome funeral rituals to their elaborate tales of the afterlife. But in fact this death-obsessed civilisation led very rich lives indeed. The River Nile provided fertile soil for crops and thick grasses for grazing animals, so it should come as no surprise that the majority of the population were farmers. Other common professions included craftsmen like carpenters, weavers and jewellers, while people from wealthier families could go on to become scribes or priests.

In the time of the Old Kingdom, Egypt did not have a standing army. It was surrounded by deserts and seas that formed natural defences, and the pharaoh would simply call upon peasants when an army was needed to defend the country. But when Egypt was invaded by the Hyksos (a Canaanite tribe), it was decided that a permanent army of trained soldiers was needed. The units included charioteers, archers and infantry, and the army was seen as a way for men to rise up through the rigid social hierarchy of the ancient kingdom. The river allowed transport and communication from one end of the kingdom to the other, helping to create a strong, unified nation and – most importantly – a strong, unified army.

Egyptian boys from wealthy families attended school, where they studied religion, reading, writing and arithmetic, while poorer boys learnt their father's trade. Girls were educated at home or went out to work, until they married at around the age of 12 – often to a man chosen by their parents. Though women were expected to obey their husbands, in many ways they were equal to men. They could participate in business deals, own land and represent themselves in court. As well as looking after their children and the household, they were able to work on farms or be employed by the courts and temples as acrobats, dancers and musicians. Noblewomen could even become priestesses and government officials. The Egyptians valued family life, and uncles, aunts and grandparents would all live together under the same roof – often in the same room.

Inside an Egyptian home

Extended families lived together in these mud-brick houses, often spending as much time on the roof as indoors!

Ventilation
Ancient Egyptian houses had vents on the roofs and high windows to allow cool air to circulate, while preventing direct exposure to the elements and discouraging intruders.

Strong walls
Like many houses of the ancient world, the walls were made of mud – 'adobe' – bricks. Mud was dried under the sun in wooden moulds and the bricks were then covered in bitumen to make them waterproof.

700
The estimated number of hieroglyphs in the Ancient Egyptian writing system

Front door
This would have been made out of thick wood with a system of wooden safety locks.

Entrance hall
The first room on entering the house would have been elaborately decorated, with a shrine to honour the god Bes, who was the protector of the family.

What did Egyptians do if their pet cat died?

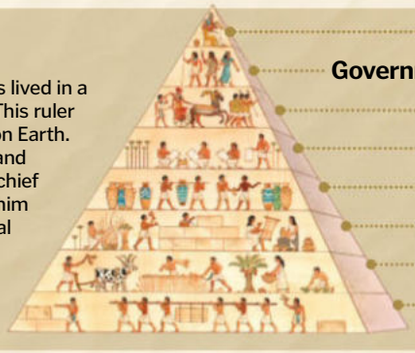
A Shave their eyebrows **B** Eat it for dinner **C** Celebrate

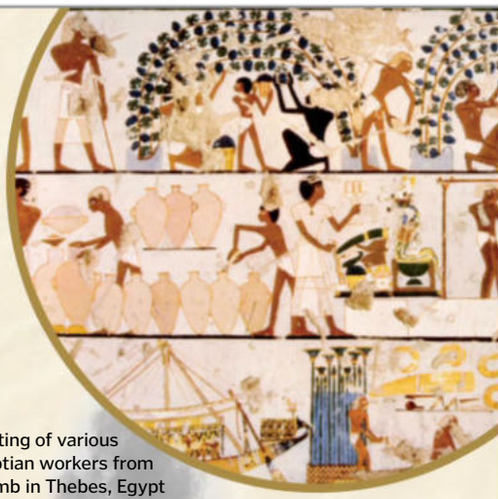
Answer:
In Ancient Egypt, cats were considered sacred creatures because of their passion for killing vermin and snakes. When a cat died, it was mummified like a human and the family would shave their eyebrows to signify their loss.

DID YOU KNOW? *The Great Pyramid at Giza was the tallest manmade structure in the world for over 3,800 years*

Egyptian society

Like many kingdoms of the ancient world, Egyptians lived in a hierarchal society with a supreme ruler at the top. This ruler was called the pharaoh and was considered a god on Earth. The pharaoh decided the laws, collected the taxes and waged war. Below the pharaoh was the vizier – his chief advisor and sometimes also the high priest. Below him were the nobles, who were responsible for individual regions, as well as other priests. Scribes were also respected, as they were the only people who could read or write, and therefore the only people who could keep records of the Egyptian dynasty.





Painting of various Egyptian workers from a tomb in Thebes, Egypt

Roof
People often slept and worked on the roof. They also dried and salted meat and fish up here.

Decoration
Walls would have been white washed and some were decorated with geometric patterns or pictures.

Kitchen
The kitchens were well equipped, with designated areas for cutlery, utensils and jars. They also had clay ovens, in which they baked bread and other foods.

Bedroom
The Ancient Egyptians slept on mats that could be rolled out, or on beds made of threaded hemp with a wooden headrest and a mattress filled with wool or straw.

Basement
This area would have been used to store food and valuables, and was often accessible via a trap door.

Living room
The Egyptians have been credited with inventing the living room – a central room where members of the family ate and socialised. These would have had stools, tables and ceramic vases, with the best pieces of furniture made from carved and painted wood.

1,000+
The number of gods worshipped by the Ancient Egyptians

"The heart was left in the chest, as it was believed it would be needed in the afterlife"

Death and rituals

It is perhaps the way Egyptians dealt with death that fascinates us most about this civilisation. These were staunchly religious people, and they worshipped over 1,000 gods and goddesses, all representing different aspects of life or death. The temples were the centre of Egyptian life, and priests were some of the most powerful people in the country, able to perform spells, surgery and sacrifice.

One of the most important facets of the Ancient Egyptian religion was their belief in the afterlife. Priests told elaborate stories of what lay beyond the grave, and how your heart would be weighed by the gods to determine how well you had lived – and ultimately, whether you would be granted eternal life. Egyptian funerals were therefore centred on preparing the body for the afterlife, ensuring that the deceased had all they would need to see them through to the end of days.

The Egyptians believed the best way to do this was to create a body that would remain intact, so it could continue to house the person's soul after death. This involved mummification, although it was a privilege of the wealthy as it was a long and expensive process. When an Egyptian died, a cut was made in the left-hand side of their body through which the organs were removed, before being placed in canopic jars. The heart was left in the chest, as it was believed it would be needed in the afterlife, while the brain was pulled out through the nose and thrown away.

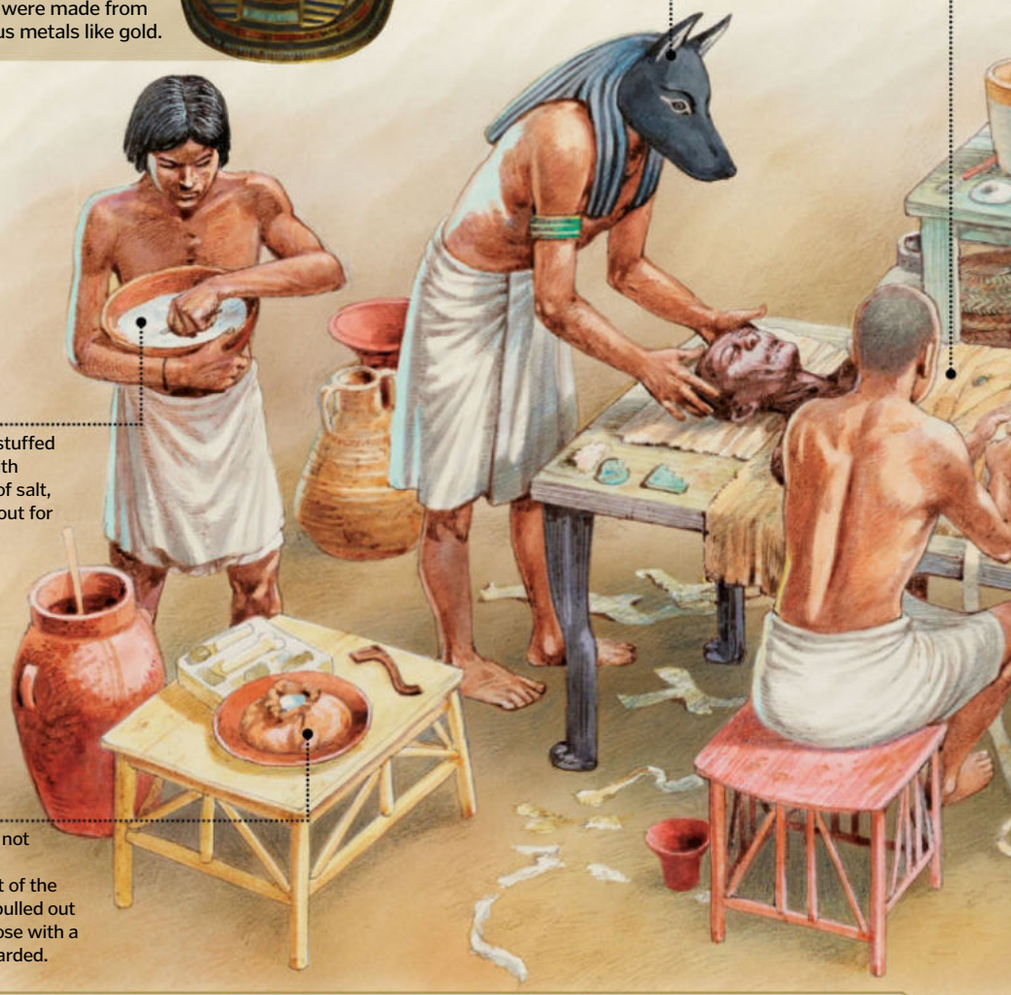
The body would then be covered and stuffed with a salty substance called natron and left to dry out for 40 days, after which time a burial mask was placed over the head of the deceased and the body sealed in a sarcophagus. These were often made of precious materials to ensure they would last for millennia to come. The body was then taken to the tomb where it would be buried along with furniture, statues, food and other items that would be useful to them in the next life.

Making a mummy

The mummification process was a messy one, involving disembowelment, dehydration and magic

Death masks

Ancient Egyptians believed that after death, the spirit would return to the body to live within it. Death masks allowed the spirit to recognise its body. Most were made of cartonnage – made from papyrus and plaster – but royal death masks were made from precious metals like gold.



Heart
The heart was not removed from the body, as it was believed to be the centre of intelligence and was needed in the afterlife.

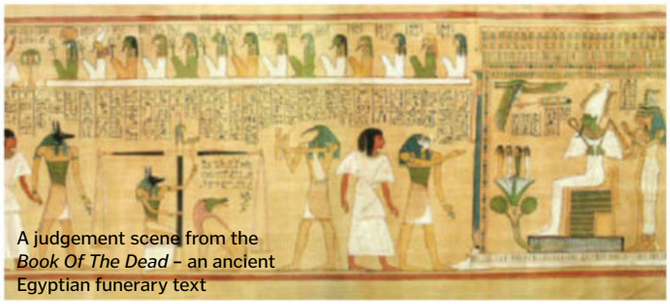
Priest
A priest was often present and wore a mask of Anubis – the god associated with the embalming process and the afterlife.

Natron
The body was stuffed and covered with natron, a type of salt, and left to dry out for 40 days.

Brain
The brain was not considered an important part of the body, so was pulled out through the nose with a hook and discarded.

The afterlife

Egyptian believed that after death, the spirit was led by the god Anubis into the Hall of Two Truths, where its heart was weighed against the Shu feather of truth. If it was lighter than the feather, they could pass on to be welcomed by the god Osiris, but if it was heavier, they would be devoured by the demon Ammit.



A judgement scene from the *Book Of The Dead* – an ancient Egyptian funerary text

KEY DATES
THE RISE AND FALL OF ANCIENT EGYPT

Ca 3000 BCE
King Menes becomes the first pharaoh to rule over a unified Egypt, beginning the era of dynasties.

Ca 2700 BCE
The first pyramid is built, which still stands today at just over 60m (197ft) tall.

1279 BCE
King Ramesses II ascends to the throne, marking the start of Egypt's most powerful epoch.

196 BCE
The Rosetta Stone is carved, containing text in Egyptian hieroglyphs and Greek.

30 CE
Queen Cleopatra loses the Battle of Actium and commits suicide, and Egypt becomes part of the Roman Empire.

DID YOU KNOW? *Dung beetles were sacred to Ancient Egyptians; a symbol of the forces that moved the Sun across the sky*

Burying the dead

The bodies of Egyptian kings were entombed within pyramids or buried deep underground to protect them from grave robbers. The interior walls were elaborately decorated and the tombs were packed full of treasures, food and furniture that they believed would be needed in the afterlife. Statues called ushabti were also put in the tomb to act as servants in the afterlife. Meanwhile, noblemen were buried beneath basic, elevated platforms called mastabas, and the bodies of peasants were simply wrapped in cloth and buried in the desert, along with everyday objects like dishes and food.

Some of the treasures found in Tutankhamun's tomb

Oil and water
Before mummification, the body was washed with palm wine and water from the Nile.

Amulets
Charms called amulets were placed between the layers of bandages. These were believed to protect the person in the afterlife.

Stuffing
After the body had dried out, it was stuffed with sawdust and linen to make it look lifelike before being wrapped in linen.

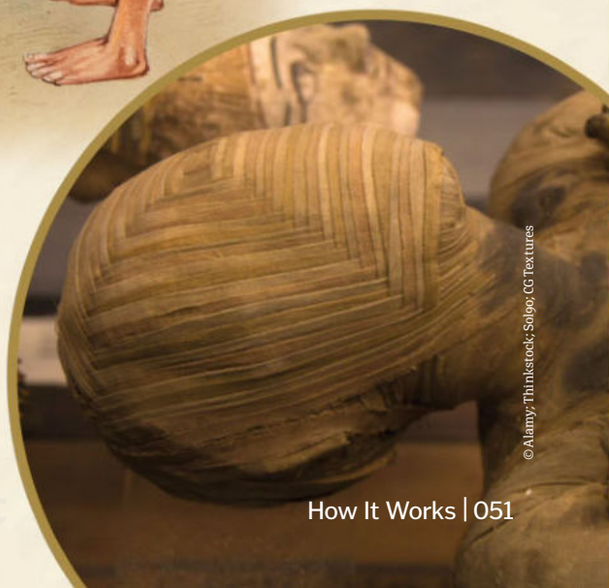
16
The Great Pyramid at Giza weighs this many times as much as the Empire State Building

Canopic jars
The liver, intestines, lungs and stomach were placed in canopic jars, which were decorated with the heads of different gods.

Linen strips
The body was wrapped in layers of linen strips, which were painted with liquid resin to glue the bandages together.

Rags
All of the fluids and rags from the embalming process were kept and buried with the body.

156
The number of children believed to have been fathered by Pharaoh Ramesses II



"A rigging system was designed to allow the ship to be operated by only a fraction of the total crew"

16th-century Spanish galleon

How did this small sailing ship change the world?

The cutting edge of European ship design at the time of its introduction, the galleon was first used in the Mediterranean Sea by the Venetian Republic, a merchant power based in the Italian city of Venice in the early-16th century, but by the second half of the century the same basic design was also in use by Portugal, England, France and Spain among others.

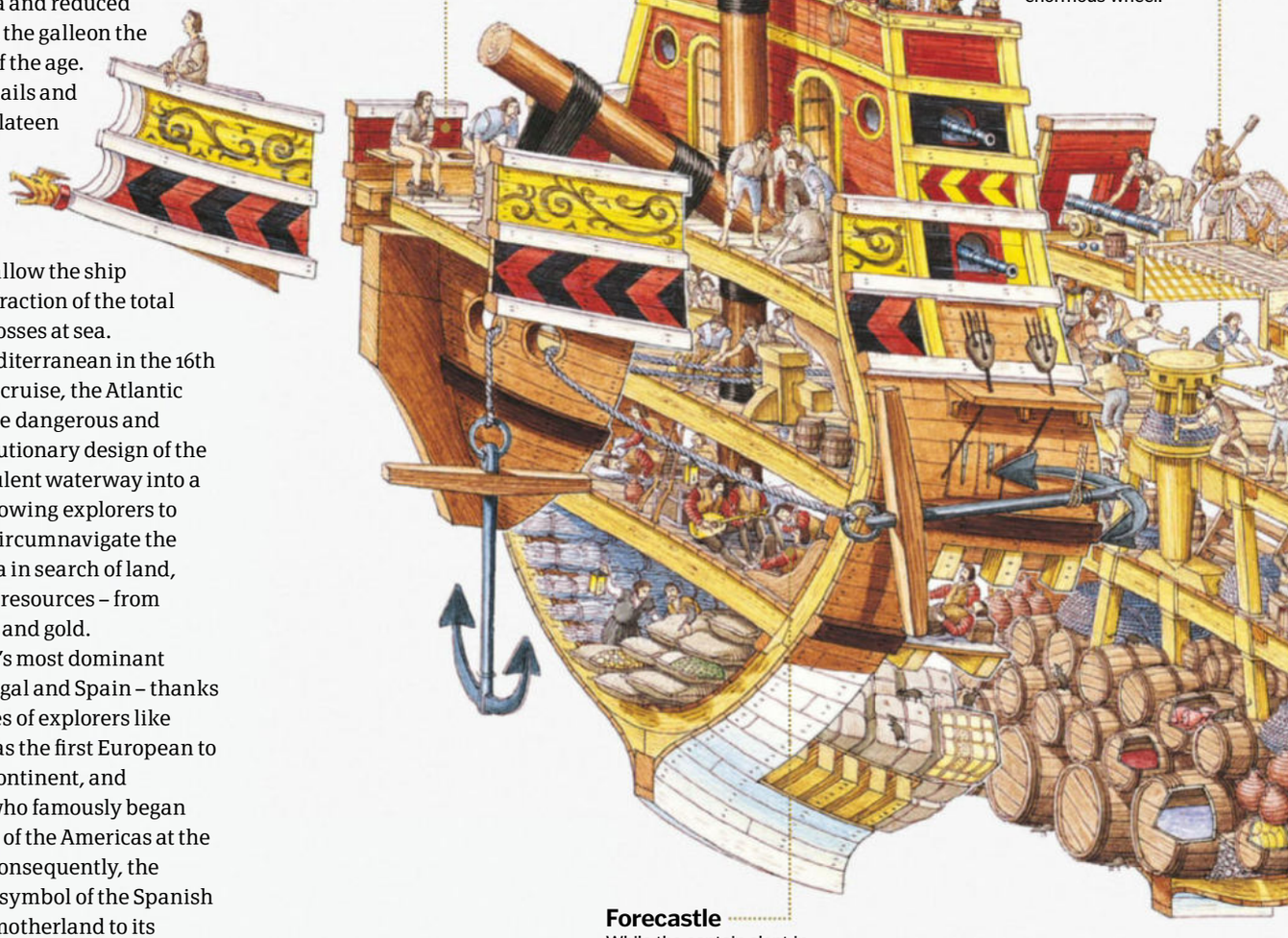
The ship's lower deck at the front (leading to that jaunty look) and long, narrow hull gave it unrivalled stability at sea and reduced wind resistance, making the galleon the fastest, nimblest vessel of the age. With three or four main sails and a single triangle-shaped lateen sail that allowed the galleon to sail against the direction of the wind, a complex rigging system was designed to allow the ship to be operated by only a fraction of the total crew should they suffer losses at sea.

While crossing the Mediterranean in the 16th century was no pleasure cruise, the Atlantic Ocean was infinitely more dangerous and unpredictable. The revolutionary design of the galleon turned this turbulent waterway into a global superhighway, allowing explorers to chart the Americas and circumnavigate the globe from Europe to Asia in search of land, trade, slaves and natural resources – from tobacco and silk, to spice and gold.

The early-16th century's most dominant naval powers were Portugal and Spain – thanks to the pre-galleon voyages of explorers like Bartolomeu Dias, who was the first European to sail around the African continent, and Christopher Columbus, who famously began the Spanish colonisation of the Americas at the end of the 15th century. Consequently, the galleon became a potent symbol of the Spanish Empire, connecting the motherland to its far-flung colonies in America, Africa, the Caribbean and Southeast Asia.

Aboard the Spanish galleon

What was life like on the high seas?



Swing guns
Small guns on pivots were used to target the crew of enemy ships and deter unwanted boarders.

Toilet
The open-air toilet wasn't actually on the poop deck; that name comes from the French word 'la poupe', which simply means 'stern.'

Capstan
The anchor was raised and lowered by an enormous wheel.

Forecastle
While the captain slept in relative luxury, the crew slept in cramped conditions at the front of the ship.

5 TOP FACTS
FAMOUS GALLEONS

1 Golden Hind
This galleon was sailed by Sir Francis Drake when he became the first Englishman to circumnavigate the globe in 1577-1580 and the second ever to do it in a single voyage.

2 Adler von Lübeck
Launched 1566, this German galleon was the largest ship of its day. It was 78.3m (256.9ft) long, carried 1,000 men and displaced 2,000-3,000t of water.

3 São João Baptista
Known as Botafogo ('fire maker') due to its 366 bronze cannons, this Portuguese galleon was the world's most powerful warship when it was launched in the 1530s.

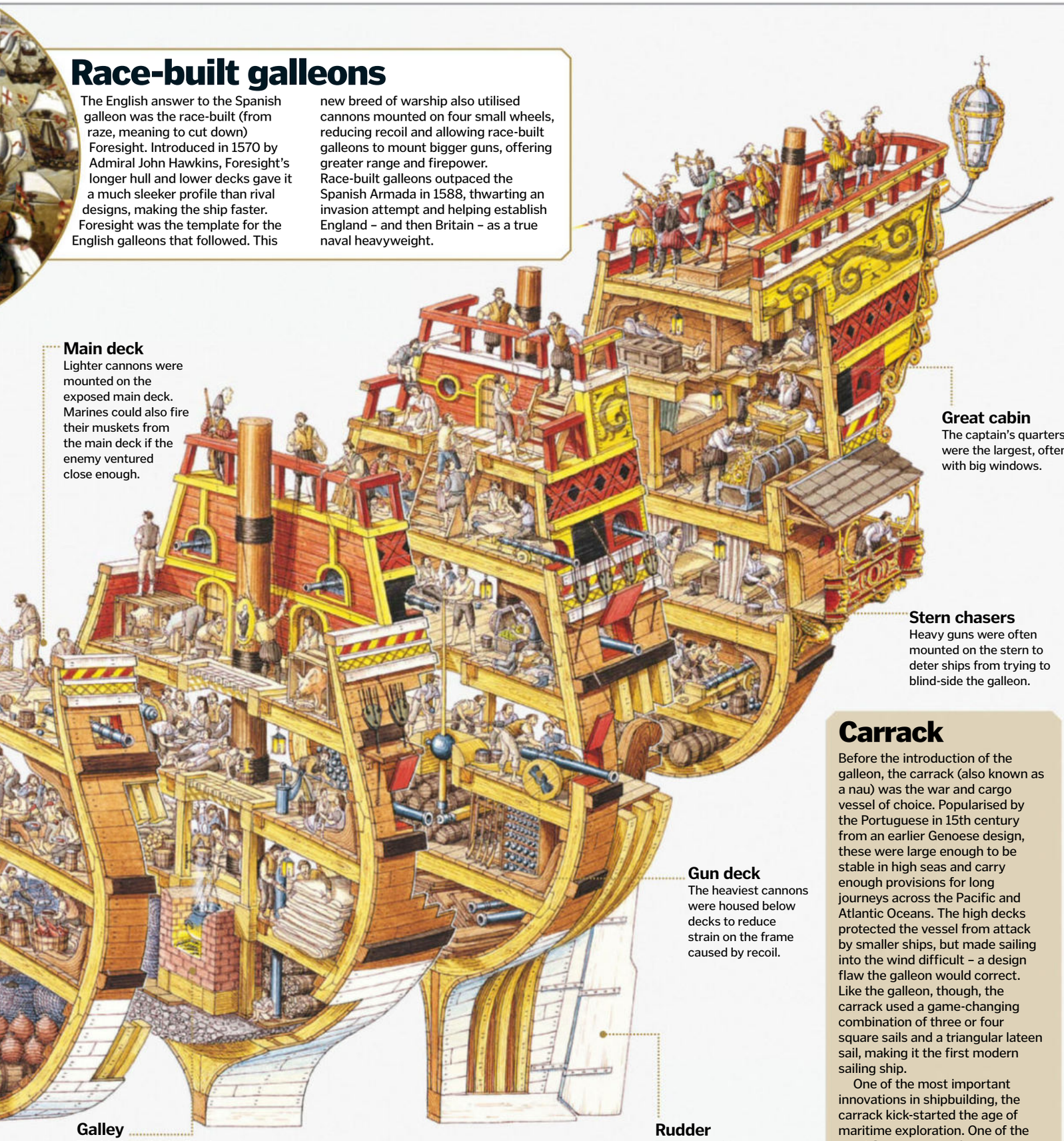
4 Ark Raleigh
First owned by Elizabethan explorer Sir Walter Raleigh, it was renamed Ark Royal in 1587, as the Royal Navy's flagship. There have since been four HMS Ark Royals.

5 Manila galleons
These Spanish galleons made regular trips from 1565 between the Philippines and Mexico. Carrying trade goods from China, they were a tempting target for pirates.

DID YOU KNOW? *The Spanish Armada that tried to invade England in 1588 had 22 galleons in its fleet*

Race-built galleons

The English answer to the Spanish galleon was the race-built (from raze, meaning to cut down) Foresight. Introduced in 1570 by Admiral John Hawkins, Foresight's longer hull and lower decks gave it a much sleeker profile than rival designs, making the ship faster. Foresight was the template for the English galleons that followed. This new breed of warship also utilised cannons mounted on four small wheels, reducing recoil and allowing race-built galleons to mount bigger guns, offering greater range and firepower. Race-built galleons outpaced the Spanish Armada in 1588, thwarting an invasion attempt and helping establish England – and then Britain – as a true naval heavyweight.



Main deck
Lighter cannons were mounted on the exposed main deck. Marines could also fire their muskets from the main deck if the enemy ventured close enough.

Great cabin
The captain's quarters were the largest, often with big windows.

Stern chasers
Heavy guns were often mounted on the stern to deter ships from trying to blind-side the galleon.

Gun deck
The heaviest cannons were housed below decks to reduce strain on the frame caused by recoil.

Galley
The kitchens had a fireplace mounted on bricks to stop the heat or sparks from setting the ship on fire.

Rudder
The long rudder was another innovation of the galleon, allowing the ship greater manoeuvrability.

Carrack

Before the introduction of the galleon, the carrack (also known as a nau) was the war and cargo vessel of choice. Popularised by the Portuguese in 15th century from an earlier Genoese design, these were large enough to be stable in high seas and carry enough provisions for long journeys across the Pacific and Atlantic Oceans. The high decks protected the vessel from attack by smaller ships, but made sailing into the wind difficult – a design flaw the galleon would correct. Like the galleon, though, the carrack used a game-changing combination of three or four square sails and a triangular lateen sail, making it the first modern sailing ship.

One of the most important innovations in shipbuilding, the carrack kick-started the age of maritime exploration. One of the most famous examples was Christopher Columbus's flagship, the Santa Maria.

"The CT-100 television set a benchmark that many companies would soon imitate"

Colour television

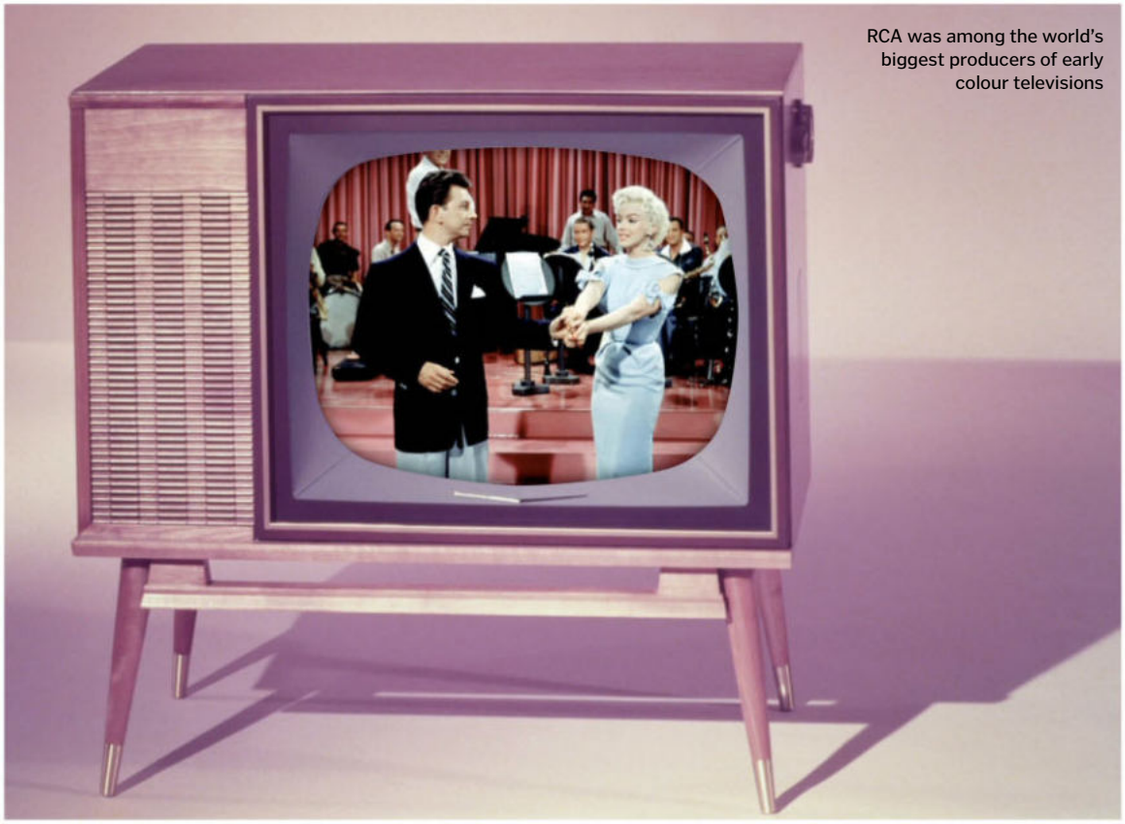
The inner workings of the first colour television

In 1954, RCA's CT-100 was approved as the first industry-standard colour television. It brought colour into previously monochrome-flooded living rooms for the first time and set a technological benchmark that many companies would soon imitate with their own models.

But how did the CT-100 bring colour images to the masses? First, light from the subject was broken down into its three colour components – red, green and blue – while being scanned. After this, the signals for the scanned images that corresponded to these three colours were combined electronically, before subsequently being separated for display in the receiver. Essentially, when these images were displayed together in quick succession, they combined to form a moving colour image.

At the time of its invention, RCA's set was in direct competition with a rival set created by CBS, which worked by passing monochrome images through a cathode-ray tube similar to the one used on black-and-white televisions, only with a colour wheel to display the images as they originally were.

While CBS's system was developed first, ultimately RCA was chosen as the industry standard thanks to its backward compatibility, which was sought after due to the large quantity of television programmes in the 1950s that were still being shown in monochrome, due to gradual technological adaptation and high costs of production.



RCA was among the world's biggest producers of early colour televisions

How Walt Disney helped save colour TV

Despite the invention of colour television, its use wasn't widespread at first. The sets were still extremely expensive, and with many programmes continuing to be broadcast in black and white, there was initially little incentive for viewers to watch the same show looking slightly different for a lot more money.

One of the shows that helped prompt a sway in attitudes was *Walt Disney's Wonderful World of Color*. As one of the first shows to provide regular programming on colour television, Disney embraced the medium to its fullest extent, even showing an introduction from Professor Ludwig von Drake (one of Donald Duck's uncles, in case you were wondering) to explain the concept for viewers. Along with other new shows like *The Flintstones* and *The Jetsons*, it was a catalyst in persuading viewers to invest in colour television sets.

Walt Disney was quick to embrace the possibilities of colour television

Colour television's first test

The first nationwide broadcast on colour televisions in the USA was the 1954 Tournament of Roses Parade in Pasadena, California on 1 January 1954 – a yearly event that celebrates the American New Year. Considering how much colour and variety was on show at these events, it was a challenging test of colour television's capabilities. Although some viewers noticed a number of problems, for instance that the bright lights and images on show meant that viewers often had to draw the curtains in their homes in order to get clear, uninterrupted viewing, the event ultimately proved to be a great success.

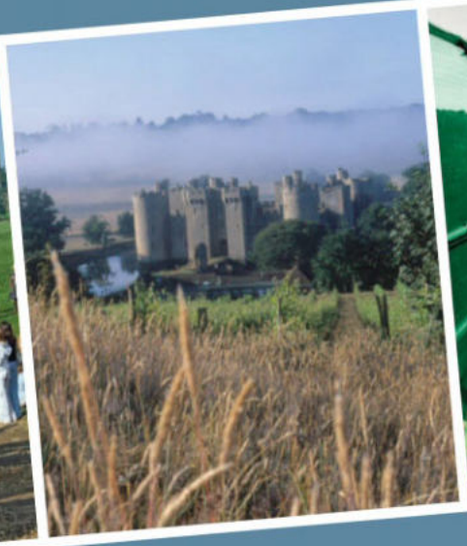
Events 2015

1066 country

Images by Bob Mazzer & Chris Parker

www.visit1066country.com/events






February

Rye Bay Scallop Week

May

Hastings, Jack in the Green

Battle Medieval Fayre

June

Great War Weekend, Kent & East Sussex Railway

August

Herstmonceux Medieval Festival

Bodiam Castle Grand Medieval Weekend

September

Bexhill Festival of the Sea

Hastings Seafood & Wine Festival

October

Hastings Bonfire & Torchlight Procession

Battle, Re-enactment of the Battle of Hastings

Rye, Wild Boar Week, Festival of Game

November

Hastings Herring Fair

Sussex Bonfire & Torchlight Processions, Rye & Robertsbridge

Battle >> Bexhill >> Hastings >> Herstmonceux >> Pevensey >> Rye

"The Whippet relied on four machine guns mounted on its fixed turret, which proved devastating to infantry"

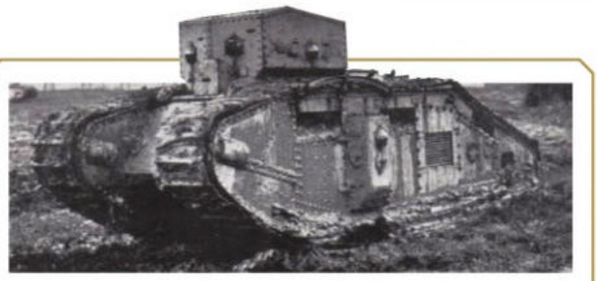
Inside a Whippet tank

The fastest British tank of WWI, the Whippet was a deadly mobile gun nest

The only British medium tank to see action in World War I, the Medium Mark A – later known as the Whippet – was proposed by businessman William Tritton on 3 October 1916 and developed by his chief engineer, William Rigby. Tritton, along with Lieutenant Walter Wilson, was the inventor of the Mark I heavy tank and the Little Willie prototype, and he saw a gap in the battlefield for something faster than the Mark I's less-than-impressive top speed of 5.9 kilometres (3.7 miles) per hour.

Able to hit 12.9 kilometres (eight miles) per hour the Medium A wasn't the hammer that delivered the battlefield's killing blow like the Mark I, but was designed to be more of a chisel, able to force open the weak points already subject to infantry assault, artillery bombardment or assault from the heavier models. While the Mark I's main weapons were its two six-pounder naval guns, the Whippet relied on four machine guns mounted on its fixed turret, which proved devastating to infantry caught in the open.

On 24 April 1918 just seven tanks ambushed two German infantry battalions near Cachy in Northern France and killed over 400 men. In another incident that proved just how devastating these fast-moving machine-gun nests could be, a single Medium A – called Musical Box by its crew – advanced so far on 8 August 1918 that it was completely cut off. Musical Box spent nine hours rampaging behind the German lines, destroying an artillery battery, an observation balloon, the camp of an infantry battalion and raiding a column of German infantry before bullets pierced a petrol can, causing fuel to leak and fill the cabin with fumes. Fighting on in their gas masks, a field gun finally disabled the tank. Amazingly, two of the three crewmen survived and were taken prisoner.

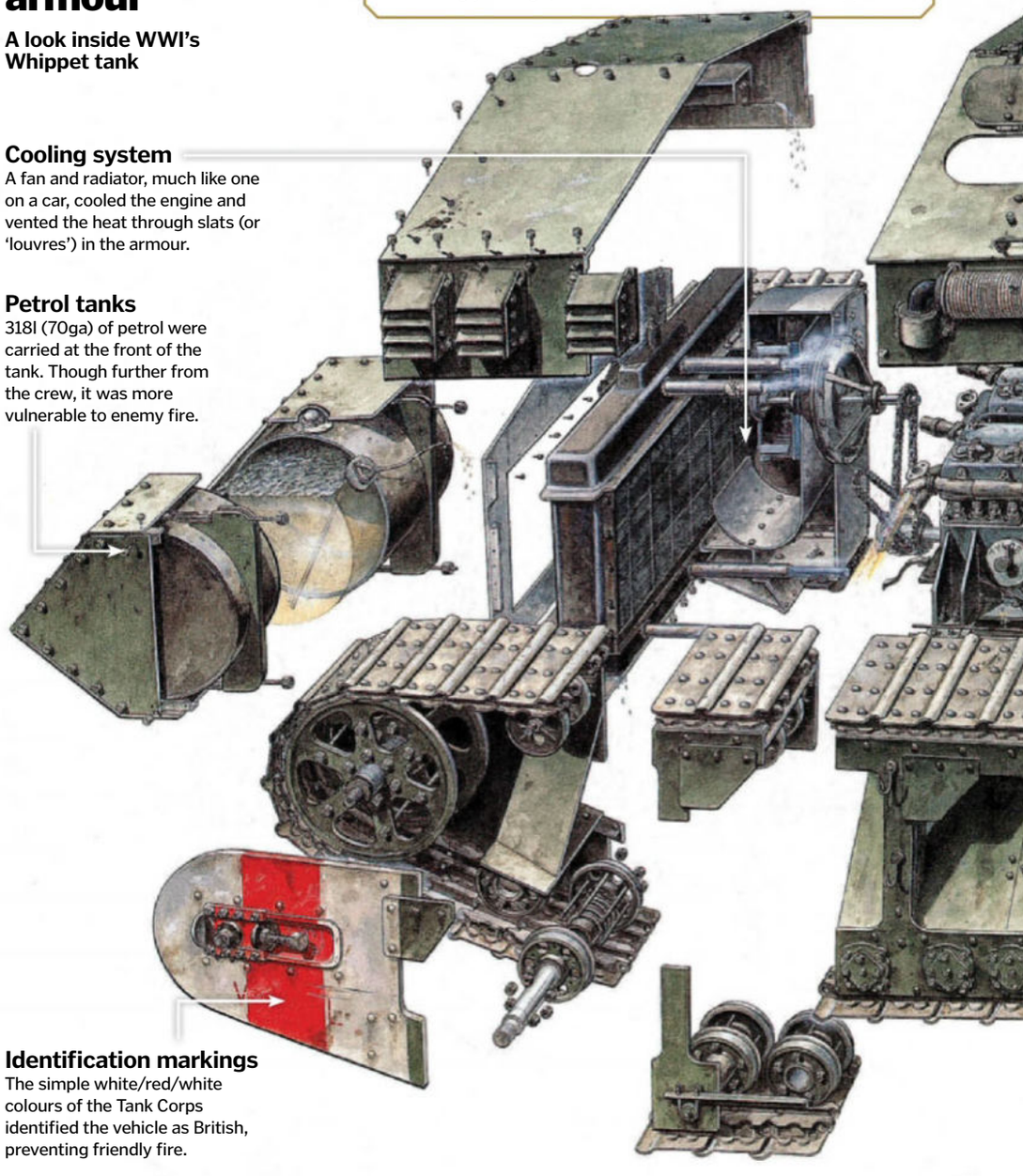


Son of Whippet

Mark I co-creator Walter G Wilson had been left out of Tritton's Medium A project and thought he could do better. The Medium B's real innovations was the sloped armour at the front of the hull, the ability to lay a smoke screen and having the crew in a separate compartment from the engine – all now standard features in tank design. The first prototype was ready in September 1918, but the end of the war on 11 November 1918 led to the order being cancelled with only 100 tanks in service. Confusingly enough, the Medium B was also called Whippet.

Behind the armour

A look inside WWI's Whippet tank

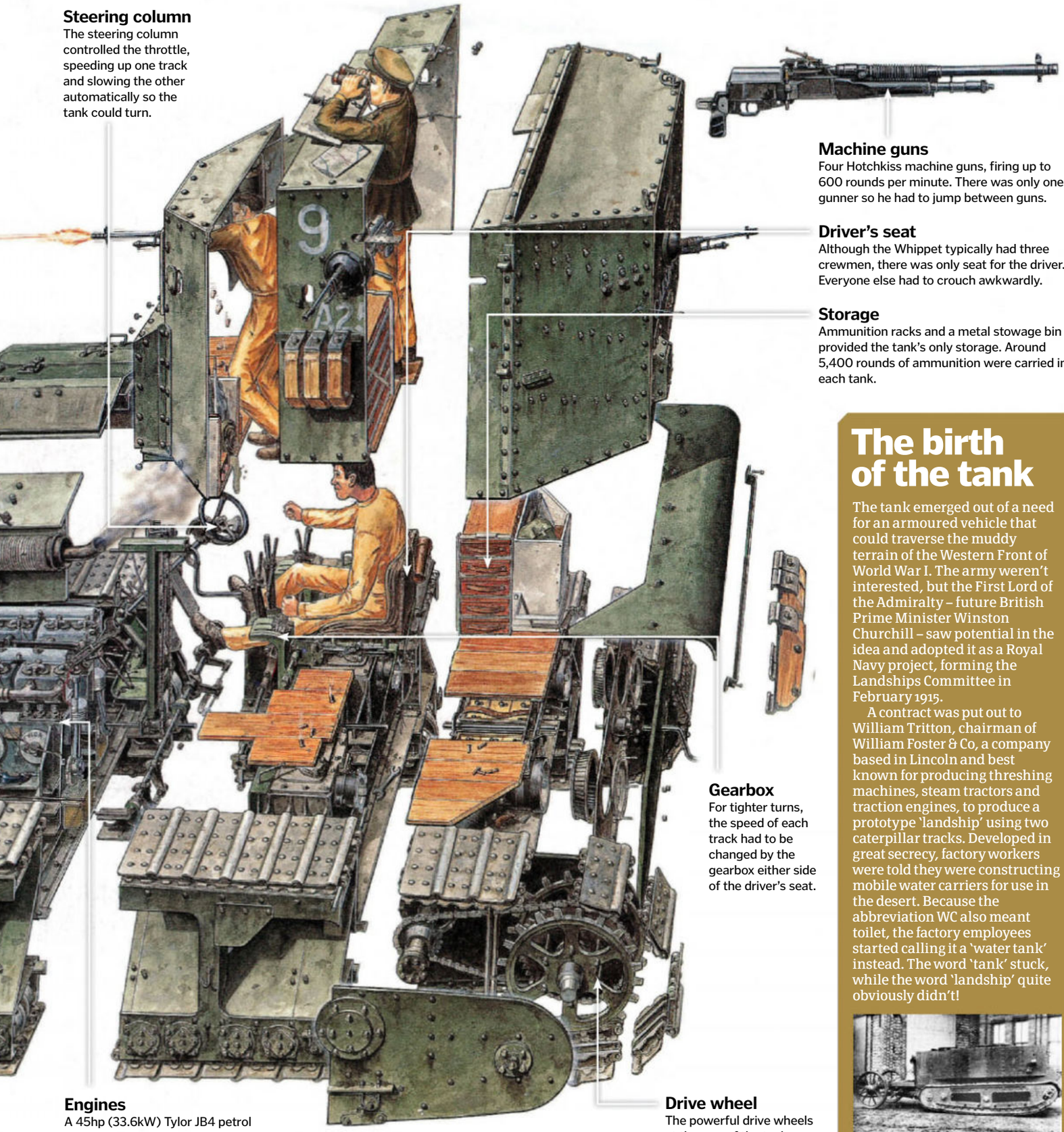


THE STATS
WHIPPET STATS

PRODUCED 1917-18 | WEIGHT 14 tons | LENGTH 9.1m (20ft)

ARMOUR THICKNESS 14mm (0.55in) | WIDTH 2.62m (8.6ft) | HEIGHT 2.75m (9ft)

DID YOU KNOW? *A small number of Whippets were sold to Japan and were used as late as the 1930s*



Steering column
The steering column controlled the throttle, speeding up one track and slowing the other automatically so the tank could turn.

Machine guns
Four Hotchkiss machine guns, firing up to 600 rounds per minute. There was only one gunner so he had to jump between guns.

Driver's seat
Although the Whippet typically had three crewmen, there was only seat for the driver. Everyone else had to crouch awkwardly.

Storage
Ammunition racks and a metal stowage bin provided the tank's only storage. Around 5,400 rounds of ammunition were carried in each tank.

Gearbox
For tighter turns, the speed of each track had to be changed by the gearbox either side of the driver's seat.

Engines
A 45hp (33.6kW) Tylor JB4 petrol engine drove each track. In peacetime, they were commonly used on London double-decker buses.

Drive wheel
The powerful drive wheels at the rear of the tank pulled the tracks over 16 small road wheels.

The birth of the tank

The tank emerged out of a need for an armoured vehicle that could traverse the muddy terrain of the Western Front of World War I. The army weren't interested, but the First Lord of the Admiralty – future British Prime Minister Winston Churchill – saw potential in the idea and adopted it as a Royal Navy project, forming the Landships Committee in February 1915.

A contract was put out to William Tritton, chairman of William Foster & Co, a company based in Lincoln and best known for producing threshing machines, steam tractors and traction engines, to produce a prototype 'landship' using two caterpillar tracks. Developed in great secrecy, factory workers were told they were constructing mobile water carriers for use in the desert. Because the abbreviation WC also meant toilet, the factory employees started calling it a 'water tank' instead. The word 'tank' stuck, while the word 'landship' quite obviously didn't!

The first tank prototype, Little Willie

SAVE RHINOS NOW

10% OF OUR PROFITS HELP FIGHT POACHING

An animal in crisis

In eastern Africa, poachers use automatic weapons to slaughter endangered rhinos. The animals are shot and the horns are hacked away, tearing deep into the rhinos' flesh with the rhino left to die.

Make a difference today

Ol Pejeta is a leading conservancy fighting against this cruelty. It needs more funds so more rangers and surveillance can be deployed on the ground to save rhinos from this horrible treatment.

Join World of Animals

World of Animals magazine takes a stand against these atrocities and is proud to be in partnership with the Ol Pejeta Conservancy – 10% of our profits go towards saving rhinos in the fight against poaching

Buy World of Animals at all good shops now

worldofanimalsmag @WorldAnimalsMag animalanswers.co.uk justgiving.com/olpejeta

What did the push-button telephone facilitate?

A Phone boxes **B** Phone tables **C** Prank calls

Answer:
As the new DTMF phones meant that there was often no need for an operator to re-route calls, people could use the phone with greater anonymity. With this pranking became easier, and thus a whole new pastime was born!

DID YOU KNOW? *The Braille version of* Harry Potter And The Goblet Of Fire *was published in ten volumes*

The Braille system of raised dots on paper is used widely to this day

How Braille was invented

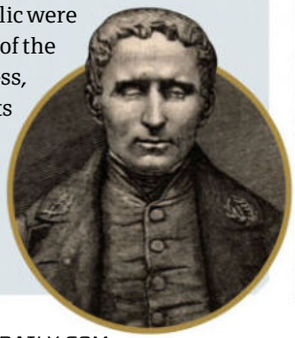
Discover how reading for the blind was revolutionised by a child

Born in 1809 in Coupvray, France, Louis Braille overcame the loss of his eyesight to create a system of reading and writing that would open doors for many a visually impaired person.

Taking inspiration from a communication system used by the French Army known as 'night writing' – which involved thick sheets of paper with dots and dashes pressed into them that could be discerned by touch – Braille chose to simplify things, reducing the number of dots to six (from the original 12) and eschewing the dashes altogether.

By the age of 15, Braille had successfully completed his alphabet and subsequently published it in book form. In later years he applied his code to mathematical and musical symbols, increasing its versatility even further.

Although the public were originally sceptical of the format's effectiveness, the genius behind its invention was eventually recognised. Today, Braille is used worldwide.



Push-button telephones

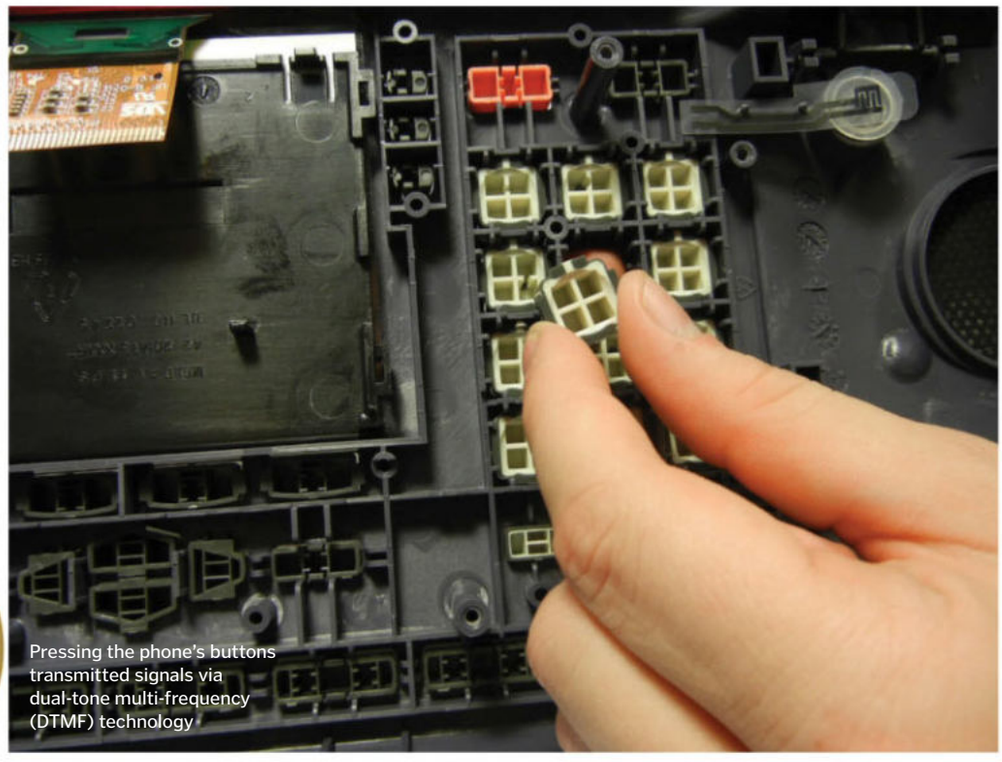
How a novel innovation revolutionised the way we speak to each other

First sold for commercial use on 18 November 1963, the push-button telephone represented a new and more efficient manner of telecommunication.

The primary difference between this new style and the old one was the adoption of dual-tone multi-frequency (DTMF) technology, also known as touch-tone dialling, which replaced the pulse dialling system used on rotary-style telephones. While pulse dialling involved rapidly connecting and disconnecting signals for each digit, with manned operators required to facilitate long-distance calls, the DTMF technology effectively cut out the middleman. Specific frequencies were assigned to rows and columns, with the dial subsequently generating a signal resulting from a combination of the two frequencies whenever a button was pressed. In turn, the tones were decoded by a switching centre in order to show which key had been pressed.

Other innovations in the invention of the push-button telephone included the microphone being disconnected whenever a key was pressed. This was done so that the resulting noise wouldn't interfere with the DTMF signal. The first model had ten buttons (numbers 0-9), but in later versions '#' and '*' keys were added in order to allow for the possibility of accessing computers through telephone lines.

Although the first device (from the Bell Telephone Company) was officially released in the 1960s, people had been working on push-button devices far earlier than that. There are prototypes from as early as 1948, with Western Electric being responsible for a number of these. Still, the Bell device proved to be revolutionary for its relative ease of use, kick-starting the telephone's ever-accelerating evolution into the smartphones we carry around today.



Pressing the phone's buttons transmitted signals via dual-tone multi-frequency (DTMF) technology

A TO Z OF THE GALAXY

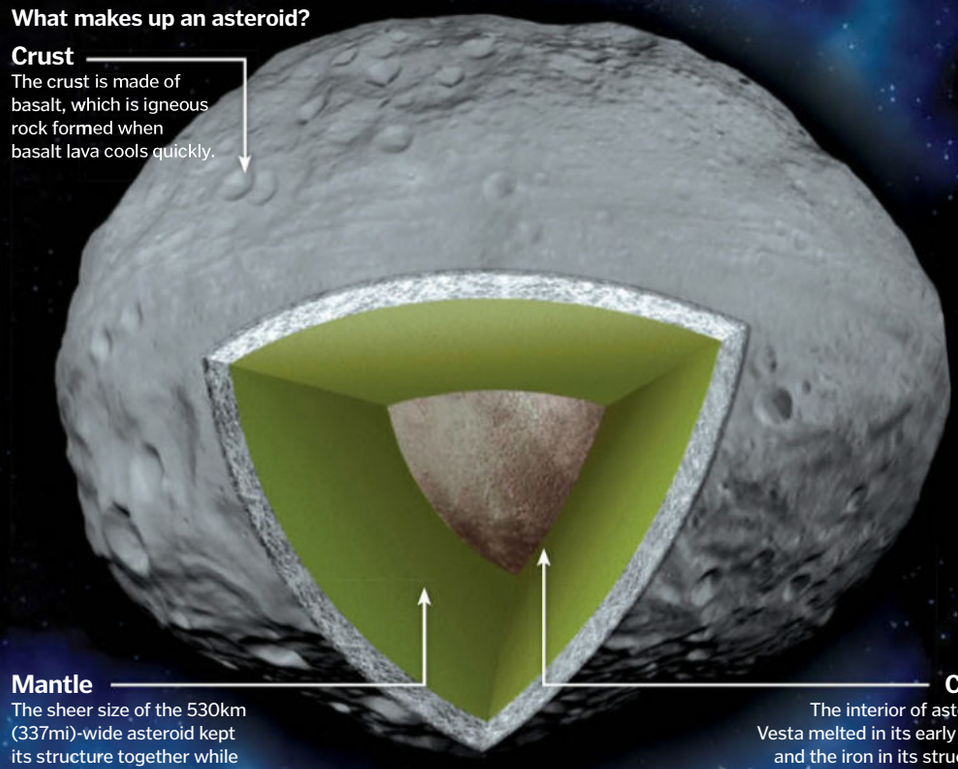
Come on a journey through the cosmos

Asteroids

There are millions of asteroids in our galaxy, ranging in size from less than a kilometre (0.6 miles) across to 950 kilometres (590 miles). The ones in our Solar System are mainly found in the Asteroid Belt between Mars and Jupiter and are made mostly of solid rock. However, they have been known to leave the belt. Asteroid groups called Atens, Amors and Apollos cross close by the Earth's orbit and can occasionally hit Earth. An asteroid would have to be at least 25 metres (82 feet) across for it to survive the journey through the Earth's atmosphere without burning up. NASA estimates that a car-sized asteroid makes it through the atmosphere every year, but will usually disintegrate before hitting the Earth. Back in 2001, NASA orbiter NEAR Shoemaker landed on the surface of near-Earth asteroid 433 Eros. Despite not being part of the original plan, Shoemaker became the first manmade object to land on an asteroid.

Inside an asteroid

What makes up an asteroid?



Crust
The crust is made of basalt, which is igneous rock formed when basalt lava cools quickly.

Mantle
The sheer size of the 530km (337mi)-wide asteroid kept its structure together while it was solidifying again.

Core
The interior of asteroid Vesta melted in its early days and the iron in its structure sunk to form the core.

5 TOP FACTS
JOHANNES KEPLER FACTS

Ministry of space
1 Kepler was originally going to be a minister in the Lutheran Church, earning a scholarship at the University of Tübingen, before becoming interested in the works of Nicolaus Copernicus.

Mars attacks
2 His first major success was working out how Mars travelled. He had hoped to solve the problem in eight days but it ended up taking him eight years.

Three's a charm
3 Having published his first two laws of planetary motion in 1609 it took Kepler a further ten years to publish his third and final law.

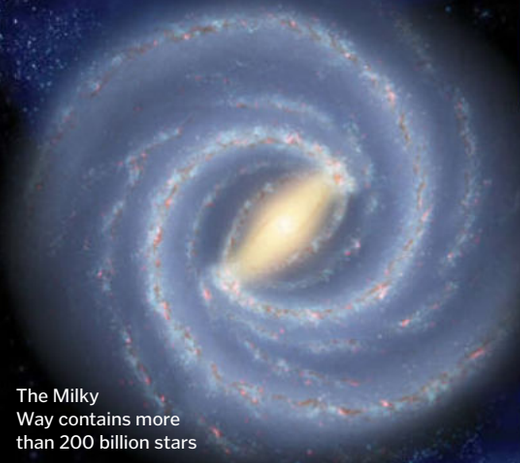
Planet hunter
4 In honour of his achievement in revolutionising our understanding of the planets, NASA named their planet-finding telescope after Kepler. The telescope launched on 6 March 2009.

King of calculus
5 Kepler's publication *Stereometrica Doliorum* formed the basis of Isaac Newton's laws of gravity as well as Newton's other famous contribution to the field of mathematics – calculus.

DID YOU KNOW? *More than 150 asteroids are orbited by a moon – some even have two satellites for company*

Barred spiral galaxy

Barred spiral galaxies are made up of an incredibly dense bar of stars, dust and gas surrounded by a number of spirals made up of less densely packed stars and dust. The Milky Way is a barred spiral galaxy and our Solar System sits on the Orion spur, a breakaway of Perseus, the western spiral arm of the galaxy.



The Milky Way contains more than 200 billion stars

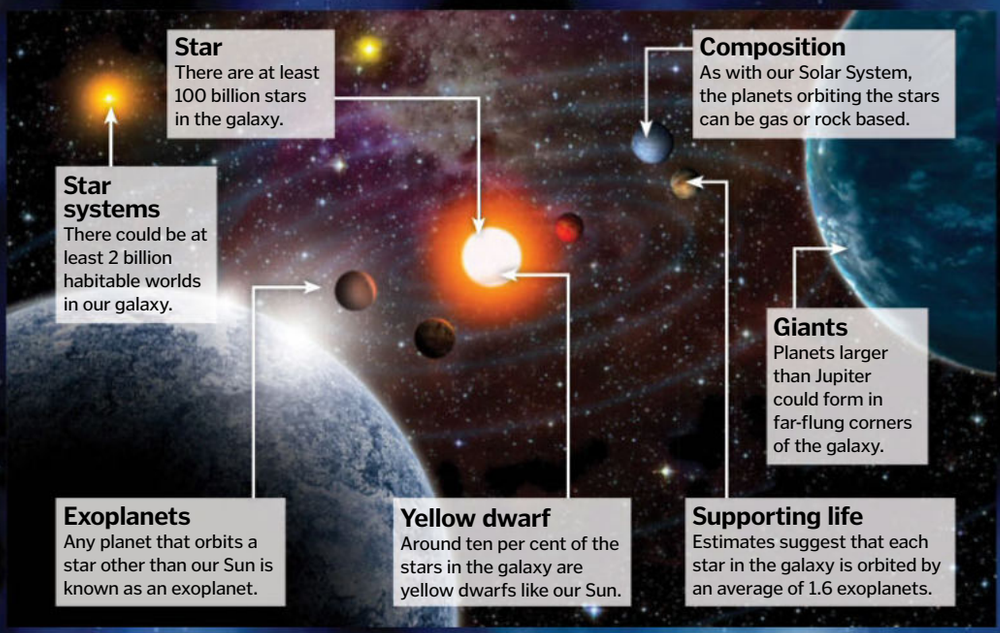
Dark matter

The existence of dark matter is currently theoretical based on the way visible matter behaves. As it doesn't reflect, give out or absorb light, scientists are still unable to detect it. Dark matter is estimated to make up around 26 per cent of the mass of the galaxy, which is over six times greater than the mass of visible matter. Scientists at CERN hope to create dark matter particles in the Large Hadron Collider, but even then they could only know of their existence due to the loss of energy inside the machine.

Dark matter around a galactic cluster is represented here in blue

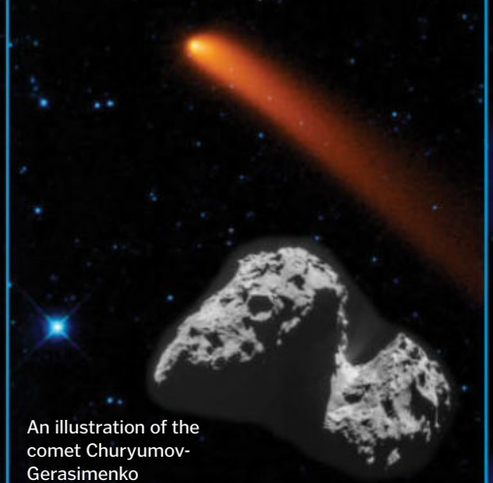
Exoplanets

An exoplanet is a planet in a solar system other than our own. One of the closest, Gliese 581g, is only 20 light-years away. Over 1,700 such planets have already been discovered, but scientists believe that there could be at least 160 billion in our galaxy alone. According to estimates, around 2 billion of these could potentially be capable of supporting life.



Comet

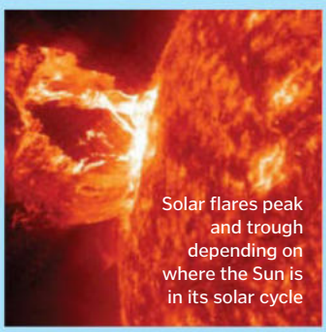
Despite looking rocky, comets are balls of ice, dust and gas. It is believed they contain remnants from the Big Bang, which is why the Rosetta mission to land on a comet was so important. Comets give off a coma of gas that looks like a tail. They usually stay in the Oort Cloud at the edge of the Solar System.



An illustration of the comet Churyumov-Gerasimenko

Flares

Flares occur when magnetic energy on the Sun (or other stars) builds up, and is suddenly released, heating the surrounding plasma to temperatures of up to 100 million degrees Celsius (180 million degrees Fahrenheit). The three stages of a solar flare are the precursor stage, where the energy starts to build up; the impulsive stage, where the particles begin to accelerate and are emitted; and finally the decay stage, where the flare subsides. Earth is protected from the radiation emitted in flares by its magnetic field, but high solar-flare activity is capable of knocking out our radio signals because the X-rays emitted disrupt the ionosphere.

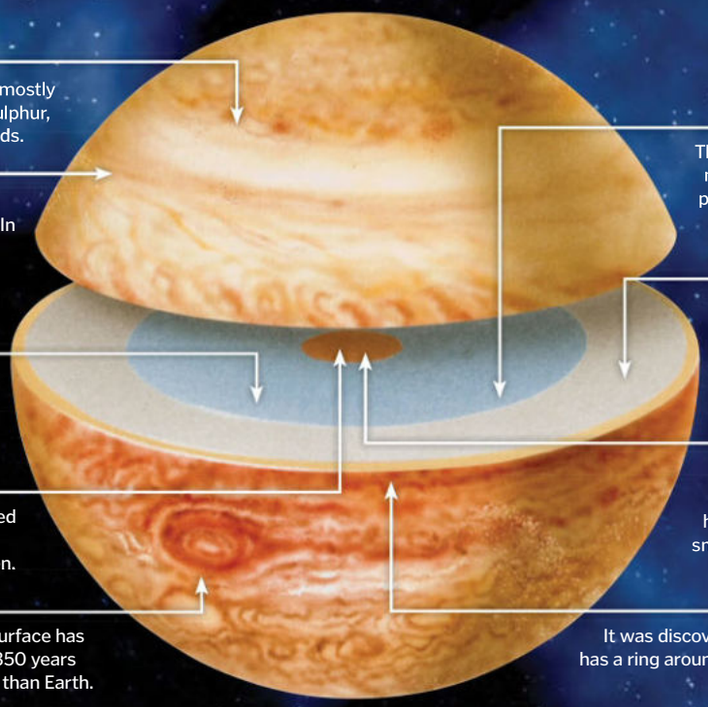


Solar flares peak and trough depending on where the Sun is in its solar cycle

"A loosely bound group of young, hot stars is called an open cluster. They form inside a molecular cloud"

Gas giants

Gas giants like Jupiter and Saturn are found in star systems across the galaxy. Some are known as "hot Jupiters" because although they resemble our neighbourhood's largest planet, they orbit much closer to their parent stars. All gas giants have thick atmospheres of hydrogen and helium, surrounding either rocky or metallic cores.



Surface
The surface of Jupiter is mostly ammonia crystals and sulphur, which form swirling clouds.

Orbit
Jupiter orbits the Sun at 780mn km (485mn mi). In other star systems, gas giants can orbit even closer to their stars than Mercury does.

Body
Jupiter is built up of layers. The closer to the core it gets, the denser the layers are.

Core
Jupiter's core is composed of rock surrounded by a layer of metallic hydrogen.

Great Red Spot
This storm on Jupiter's surface has been raging for at least 350 years and is three times larger than Earth.

Gravity
The mass of Jupiter's core means the gravity on the planet is 2.4 times that of Earth.

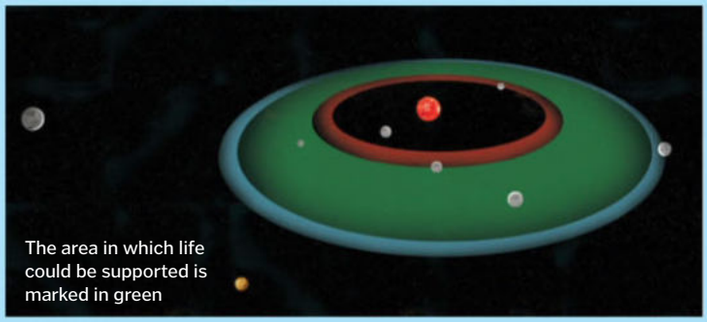
Temperature
The core of Jupiter measures an incredibly hot 35,000°C (63,000°F), six times the temperature of Earth's core.

Composition
90 per cent of Jupiter is hydrogen, ten per cent helium and there is a tiny smattering of other gases.

Ring
It was discovered in 1979 that Jupiter has a ring around it like Saturn, however Jupiter's is much fainter.

Habitable zone

Also known as the Goldilocks zone, the habitable zone is an area around a star that could sustain life. Like in Earth's case, it needs to be close enough to the star to provide heat to its inhabitants but not so close it boils water on the planet. The exoplanet system around star Gliese 667C is thought to have three planets orbiting in its habitable zone.



The area in which life could be supported is marked in green

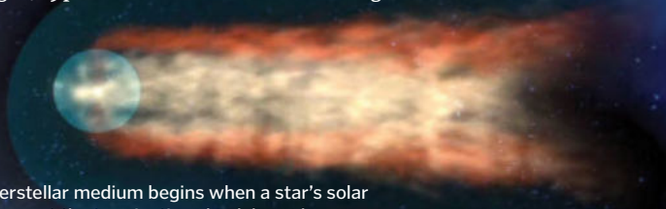
Jets

Jets are streams of particles emitted by black holes. Sagittarius A*, the black hole at the centre of our galaxy, fires a jet into the galaxy once a day. It is thought they are the result of objects such as asteroids falling into the black hole and being expelled. The jets run into gas around the black hole and produce X-rays, so we are able to detect them using telescopes such as Chandra.

Jets of particles streaming either side of Sagittarius A*

Interstellar medium

The area between stars is the interstellar medium, found in regions where the solar wind streaming from a star is countered by the interstellar wind. The gas is about 75 per cent hydrogen, 25 per cent helium and is found in the form of cold hydrogen clouds or hot ionised hydrogen. Having been launched in 1977, NASA announced that their Voyager 1 probe had reached the interstellar medium in August 2012.



The interstellar medium begins when a star's solar wind drops at the termination shock boundary

Kepler's laws

Johannes Kepler's laws of planetary motion describe how planets orbit stars. The first law explains why the orbit of the planets in our Solar System are elliptical, while the second and third laws provide the model for astrophysicists to map where planets will be at any one time. Despite being formulated from data collected by his mentor Tycho Brahe in the early-17th century, the laws still hold up today.

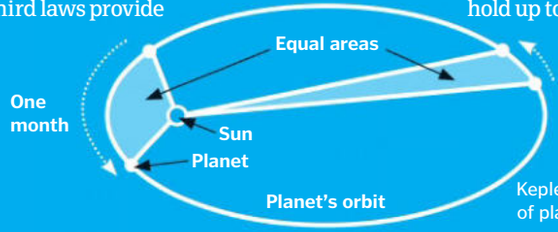


Diagram demonstrating Kepler's second law of planetary motion

RECORD BREAKERS
LONG-DISTANCE TRAVELLER

19.5bn km

FURTHEST MANMADE OBJECT

Since it left Earth 37 years ago, Voyager 1 has travelled 19.5bn km (12.1bn mi) – at the time of writing – becoming the furthest manmade object from Earth. Voyager 2 is about 3.5bn km (2.2bn km) behind.

DID YOU KNOW? *Since the first one was found in 1992 it has taken just 22 years to discover more than 1,700 exoplanets*

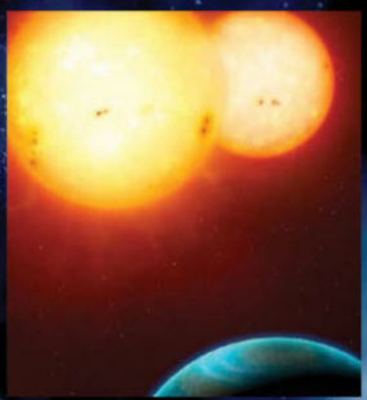
Local Group

Our galaxy is part of a group of at least 30 galaxies that are known as the Local Group. Around 20 of these are bright galaxies, the brightest of which are the Milky Way and Andromeda, our nearest neighbour. The Local Group is spread over 10 million light years, but this will inevitably change as it is projected to get drawn into the Virgo Cluster at some point in the future.

The Triangulum galaxy (M33) is the third-largest in our Local Group after the Milky Way and Andromeda

Multiple-star system

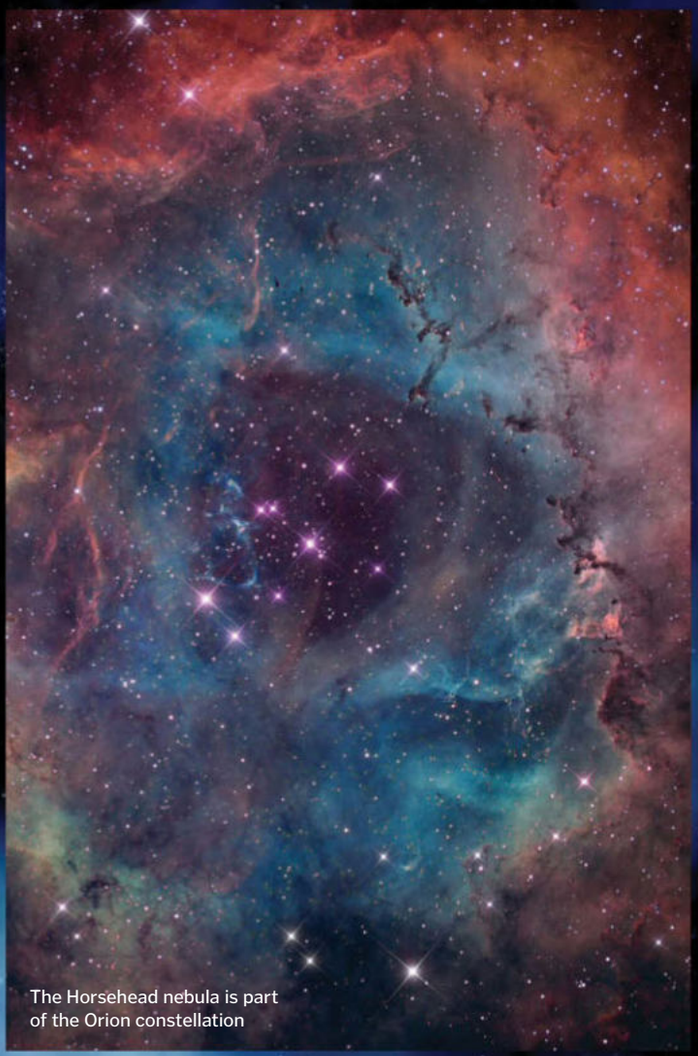
We may think planets with two suns are only found in *Star Wars*, but they do exist in our galaxy. Planets that orbit more than one star are rare as the stars' combined heat makes it much harder for planets to form. Therefore they tend to form further out than normal and then move closer toward the stars. Studies suggest that planets in binary star systems are common.



Kepler-35b orbits its two host stars once every 131 days

Nebulae

Nebulae are among the most striking images in the galaxy. Incredible visions such as the Horsehead nebula or the Rosette nebula form when the interstellar medium (see 'I' for further information) collapses. This causes the interstellar dust, hydrogen and helium to draw together due to gravitational attraction. As the nebula forms, its gravitational attraction increases, which draws even more gas and dust toward it. The core of the nebula begins to heat up and nuclear fusion takes place. That reaction sends radiation outward to the edge of the nebula, which ionises the gas and turns it into plasma. These are the ingredients needed for a protostar to become a star. Therefore, the study of nebulae is key for scientists hoping to discover how our Solar System was formed. The dark clouds of a nebula can be quite hard to see, but scientists can sometimes get lucky, as in the case of the Horsehead nebula, which is backlit by the star Sigma Orionis. Nebulae also form at the other end of the scale. When a Sun such as ours dies it turns into a red giant star, which eventually burns the last of its fuel and becomes a planetary nebula.



The Horsehead nebula is part of the Orion constellation

Open clusters

This is a loosely bound group of young, hot stars is called an open cluster. They form inside a molecular cloud, which is a collection of hydrogen molecules and is where every star in the galaxy begins to form. They tend to stay inside their molecular cloud until the radiation they give off dissipates it. As they are so loosely bound together, open clusters are prone to losing members to other systems.

The Pleiades open cluster is bright enough to be seen by the naked eye from Earth

Protoplanetary disks

It is thought that our Solar System, as well as most others in the galaxy, formed thanks to a protoplanetary disk. These start out as a protostar, which is a body that has the potential to become a star but is not yet hot enough, surrounded by a molecular cloud. Gravitational forces cause the cloud to collapse and start spinning, causing material to clump together and form planets and asteroids.

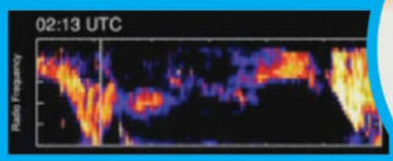
The gaps in between the disk's rings are where planets begin to form

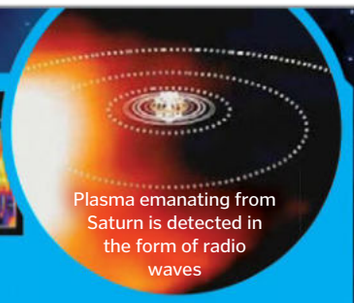
"It is estimated that there are around 230 Wolf-Rayet stars in our galaxy"

Quasar

A stunning representation of a quasar, one of the brightest objects in the universe

Quasars are the brightest objects in the universe, composed of streams of particles emitted by supermassive black holes. These particles exit the black hole at near the speed of light and have more energy than all the stars in their galaxy combined, releasing this as light energy. Although our galaxy doesn't contain a quasar, it's possible that it used to and could again when the Milky Way collides with Andromeda galaxy.





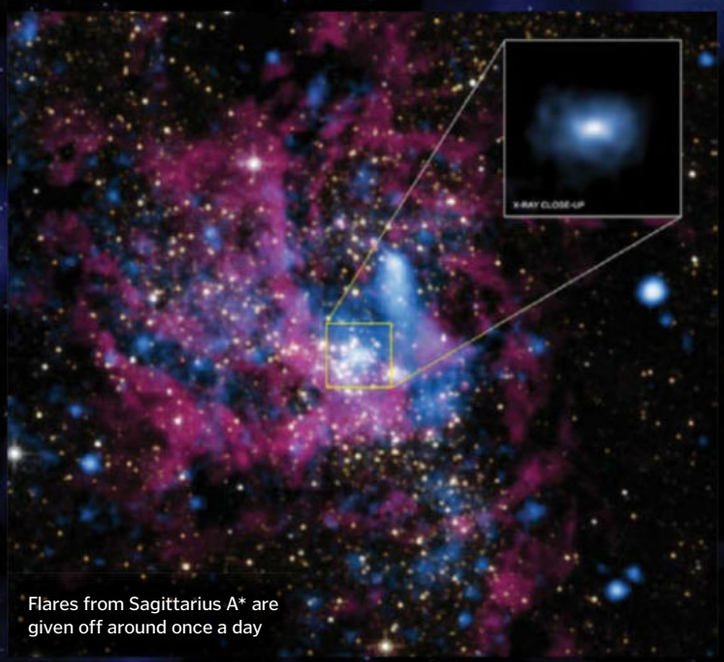
Plasma emanating from Saturn is detected in the form of radio waves

Radio waves

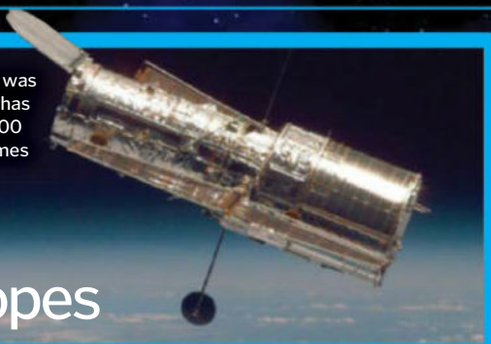
Stars such as our Sun emit electromagnetic radiation in the form of radio waves, which have the longest wavelength of any wave in the electromagnetic spectrum. This allows us to pick up the long-range signals, amplify them using huge dishes and learn more about objects in our galaxy. By viewing the galaxy through radio telescopes we can see further than ever before and detect far-flung pulsars and quasars.

Sagittarius A*

No A-Z of the galaxy would be complete without the mysterious object that sits at its very heart. Sagittarius A* is a supermassive black hole around which the entire galaxy revolves. Its mass is 4 million times greater than the Sun's and sits 26,000 light years from Earth. It is likely to have formed when a star collapsed in on itself, retaining all its mass but dramatically reducing in size. It will have become a supermassive black hole either by steadily acquiring matter or colliding with another black hole and combining. Almost every galaxy has a supermassive black hole at its centre, keeping all the various bodies orbiting around it thanks to its astonishingly powerful gravitational pull. Black holes are impossible to actually see as they suck in everything around them, including light. However, they can be spotted by the high-energy light produced by stars and gases in their vicinity. Having said that, some things do manage to escape from Sagittarius A*. Images from the Chandra and XMM-Newton observatories have shown incredible X-rays, gamma rays and flares being given off from the black hole. It can also be detected by observing the effects of its immense gravity on the surrounding area.



Flares from Sagittarius A* are given off around once a day



The Hubble telescope was launched in 1990 and has carried out nearly 4,000 observation programmes

Telescopes

Telescopes come in many forms, helping us study the galaxy. There is the Very Large Telescope (VLT) array, which combines its four 8.2-metre (26.9-foot)-wide mirrors to see 25 times farther than one alone. The Atacama Large Millimeter/submillimeter Array (ALMA) consists of 66 radio antennas that receive signals emitted billions of years ago, and we can't forget Hubble, currently orbiting Earth at 28,160 kilometres (17,500 miles) per hour.

Ultraviolet radiation

If you've ever had sunburn, you are the victim of UV radiation from the Sun. Ultraviolet radiation is on the lower end of the electromagnetic spectrum, meaning that its wavelengths vibrate rapidly and can mess with our DNA. Our atmosphere mostly blocks UV radiation, however. When stars turn into white dwarfs they emit huge amounts of UV radiation that heat up the gaseous layers around them.

The Helix nebula is spewing UV radiation from its core as it dies

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

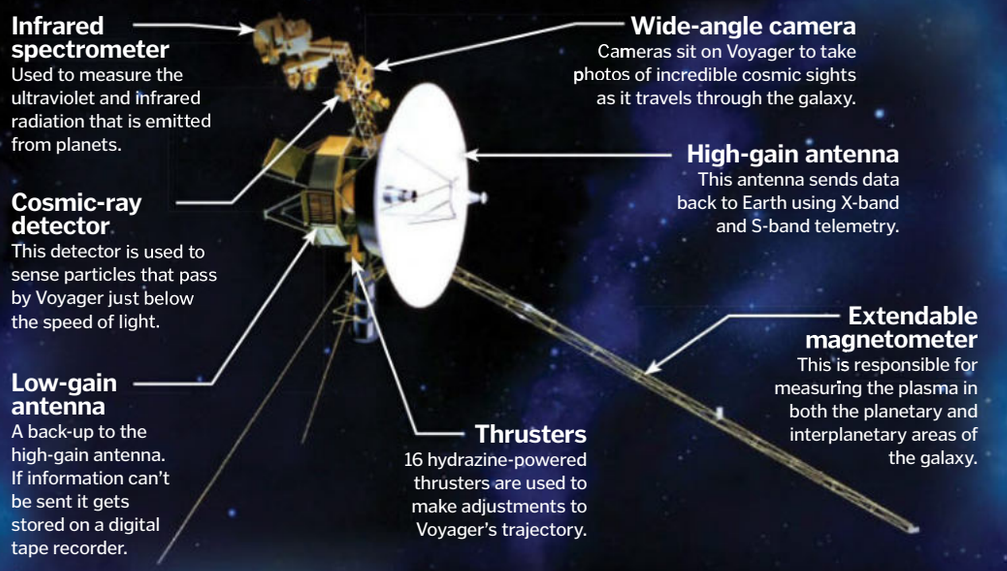
Discover the galaxy as photographed by Hubble

www.howitworksdaily.com

DID YOU KNOW? *62 years passed between the discovery of Wolf-Rayet stars and astronomers understanding their properties*

Voyager

Voyagers 1 and 2 were launched in 1977 with the brief of exploring Jupiter and Saturn. The two spacecraft returned amazing images of volcanoes on Jupiter's moon Io and Saturn's rings. Once they had mapped the two closest gas giants their mission was extended to travel farther than any manmade object had ventured before. Voyager 1 reached Uranus in January 1986 and Neptune in 1989. It then entered interstellar space in August 2012 and is transmitting data back to Earth about the unknown region between solar systems in our galaxy. Using technology developed nearly 40 years ago, Voyagers 1 are 2 are still successfully exploring the galaxy and providing data via the Deep Space Network, which is an array of radio antennas that allow data to be sent from incredible distances.



Wolf-Rayet star

When a star that is at least 20 times the size of our Sun burns out, it transforms into a red supergiant. If heavy elements manage to push their way out to the surface and cause winds to shoot gas out at incredible speeds, the supergiant becomes a Wolf-Rayet star. Only around 230 Wolf-Rayet stars that haven't detonated into supernova stage have been catalogued in our galaxy.

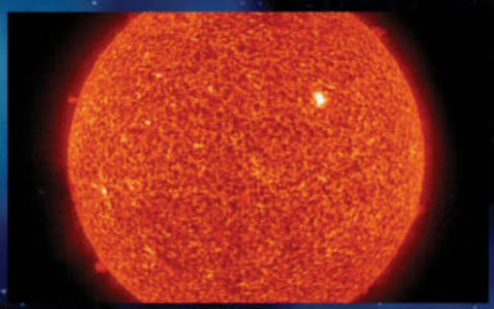
X-rays

X-rays are emitted from all kinds of galactic bodies, from stars to black holes. As virtually no X-rays are able to penetrate the Earth's atmosphere, NASA has had to send telescopes into space to detect them. They are especially useful to astronomers as they can be detected even when there is nothing visible for other telescopes to pick up. X-rays are the main type of radiation emitted from black holes.

Telescopes can pick up X-rays that give information on the location of black holes

Yellow dwarf

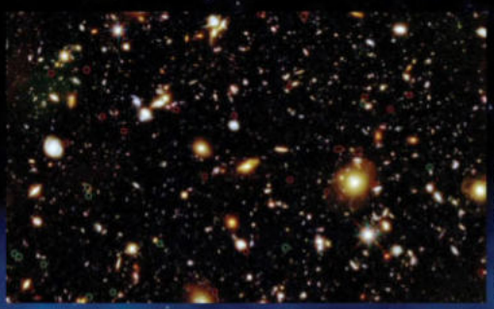
Our Sun is an example of a yellow dwarf, one of several classifications of star. These stars have a temperature range of 5,030 and 5,730 degrees Celsius (9,080 and 10,340 degrees Fahrenheit) and tend to live for around 10 billion years or so. At this point they turn into a red giant star and then collapse into a white dwarf. Our Sun has approximately 5 billion years before it turns into a red giant star.



Our Sun is one of the biggest known yellow dwarfs in the Milky Way galaxy

Z

The letter 'z' is the notation for redshift and blueshift. As wavelengths of the light spectrum change, so do the colours. If a star is moving away from us, the wavelength of its light is stretched out and becomes redder. If it is moving towards us, it appears bluer as the wavelengths get shorter. When z is positive the light is shifted toward the red and if z is negative it has blueshifted.



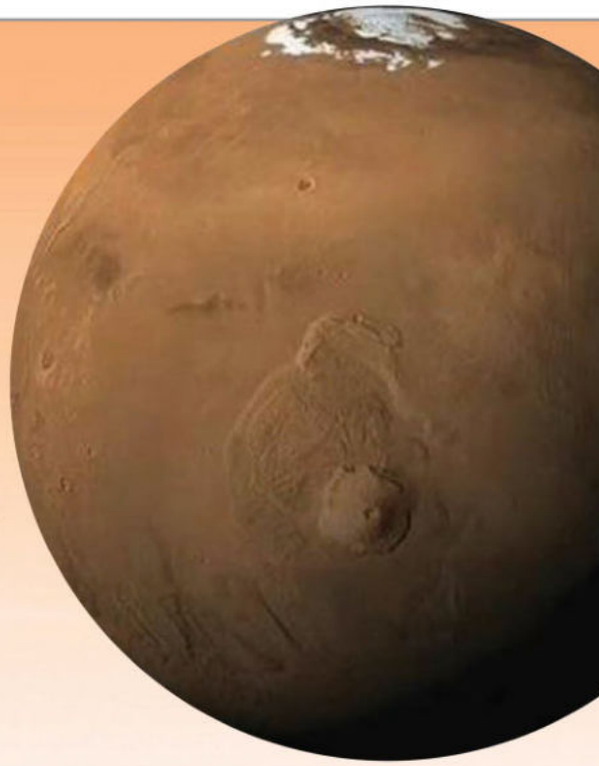
We discover how far away stars are by the amount of redshift and blueshift they exhibit

"It's an incredible two-and-a-half times the size of the tallest mountain on Earth, Mauna Kea"

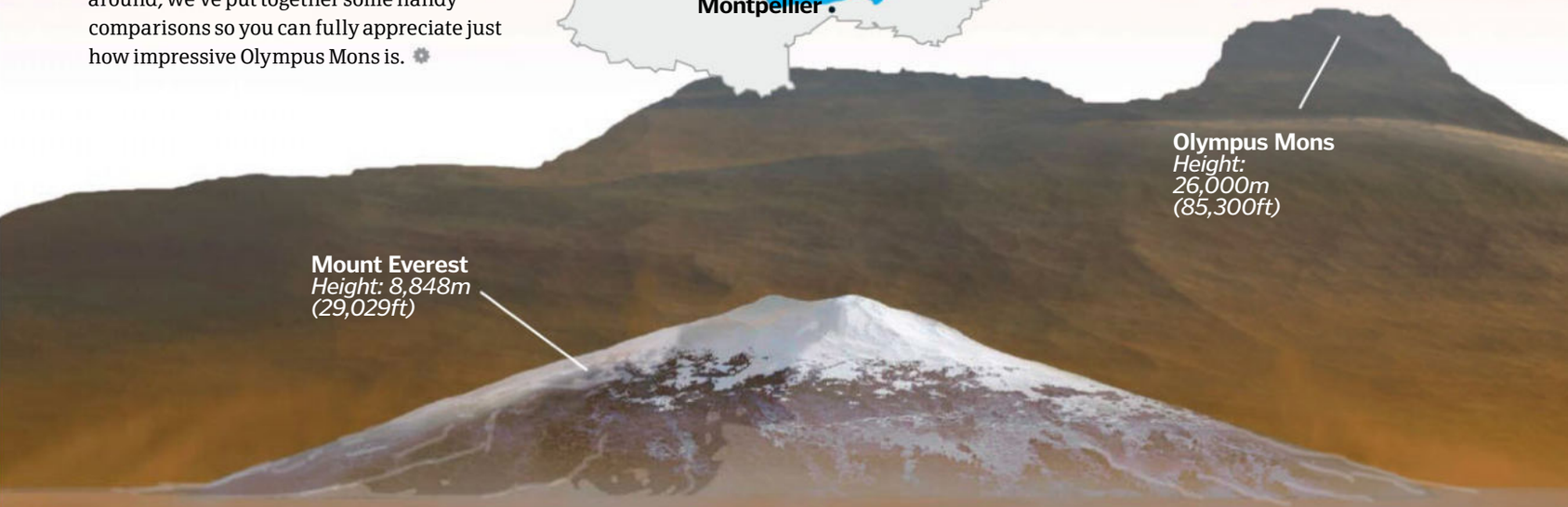
How big is Olympus Mons?

Discover how the biggest mountain in the Solar System would look on Earth

The biggest mountain in the Solar System is Olympus Mons, a 26-kilometre (16-mile) high shield volcano on the planet Mars. This makes it an incredible two-and-a-half times the size of the tallest mountain on Earth, Mauna Kea, and just under three times the height of Mount Everest. Not only is it tall, Olympus Mons is also incredibly wide, stretching 624 kilometres (388 miles) across its base. This enormous geological feature has been steadily building up longer than life has existed on Earth. As these numbers are pretty tricky to get your head around, we've put together some handy comparisons so you can fully appreciate just how impressive Olympus Mons is.



Olympus Mons is clearly visible in satellite photos of Mars



Height

At 26 kilometres (16 miles) high, nothing on planet Earth is even half as high as Olympus Mons. This is because on Earth tectonic plates move, shifting the hot spot and creating volcano chains, such as the Hawaiian islands. Mars doesn't appear to have these, so the hot spot stays in the same place, allowing a single volcano to build up. You would have to stack more than 30 of the world's tallest building, Burj Khalifa, on top of one another to reach its summit. If Olympus Mons were on Earth, it would reach up into the lower stratosphere, the second major layer of the Earth's atmosphere.

THE STATS
OLYMPUS MONS

HEIGHT	26km
WIDTH	624km
GRADIENT	5%
CALDERA DEPTH	3km
CALDERA AREA	4,800km²
VOLUME	4,000,000km³

DID YOU KNOW? *It is estimated that the last eruption of Olympus Mons took place 25 million years ago*

Formation

The formation of Olympus Mons has been a long and drawn-out process. Lava built up in the centre of Mars and erupted slowly because the planet's reduced gravity doesn't pull the lava down as quickly as on Earth. This results in a long, shallow volcano. Research has shown that Olympus Mons started its formation around 3.6 billion years ago. This is about the same time that life began on Earth in the form of bacteria and only 1 billion years after the formation of Earth itself.

These Earth stromatolites (fossil records of prehistoric microbes) started forming at the same time as Olympus Mons on Mars

Craters

As the volcano erupts lava flows out of the magma chambers. This creates a large empty space, which becomes structurally weak. As the lava solidifies and gets heavier the structure collapses in on itself. The resulting crater is called a caldera. Volcanoes can have many calderas as magma chambers build up on top of calderas, collapse and form another. Olympus Mons has six, with a depth of about kilometres (1.9 miles) below the summit of the volcano. It is approximately 80 kilometres (50 miles) in diameter and 4,800 square kilometres (1,850 square miles), making it roughly the same size as the US city of Atlanta, Georgia. Olympus Mons' craters are large because the lava flow is so slow.

Width

One of the truly incredible things about Olympus Mons is its width. It stretches an amazing 624 kilometres (388 miles) across. This is because it has been growing over billions of years by lava streaming down its sides, solidifying and building up. Eruptions are more frequent on Mars than on Earth because there is less resistance to the upsurge of lava. This provides much more material for Olympus Mons to increase in size. Olympus Mons is part of the Tharsis Montes region, which is a collection of shield volcanoes that have formed on the crustal bulge of Mars. Olympus Mons' average gradient is just five per cent. Its total base diameter is the same as the distance between London and Glasgow or New York and Pittsburgh. It would take five solid days to walk up one side and down the other.

Volume

Even though Olympus Mons may look impressive on the surface, underneath it is just as fascinating. At 4 million cubic kilometres (959,650 cubic miles), the volume of Olympus Mons is 100 times that of Mauna Loa, Earth's biggest volcano. It would hold a staggering 1.6 billion Great Pyramids and 50 times the volume of the Caspian Sea, Earth's largest lake.

SURVIVING THE BIG FREEZE

Discover how animals take on the extremes and win

The adaptive techniques that animals use to survive the temperature changes in their environment are nothing short of extraordinary. Some creatures such as Arctic ground squirrels or brown bears choose to while away winter in a deep slumber, while others like caribou or Arctic terns embark upon epic migrations to warmer climes the moment things start to get really chilly. Then there are the hardcore stay-putters, the animals that have evolved some truly wonderful – and some downright weird – ways to weather the storm. Take the Arctic tundra's musk oxen, for example; this grumpy beast has a shaggy coat made of hollow hair for warmth that hangs so low to the ground that it traps a layer of warm air beneath the animal. Couple this with a whole herd of huddling musk oxen and things get very toasty indeed.

Physical adaptation is a key weapon against the cold. Animals such as many rodent species will bulk up during the summer months in order to have sufficient fat reserves to see them through the winter. Other animals, like Arctic foxes or hares, have developed thick fur that actually changes colour with the seasons to provide both warmth and camouflaged protection.

Metabolic changes allow survival against all odds, as well as amazing chemical adaptations, like the icefish, which has antifreeze literally running through its veins.

However, surviving the chill isn't all about adapting to seasonal changes. There are some animals in ecosystems such as the deserts that have to survive the daily extremes of day-to-night temperature fluctuations, and have developed incredible methods of coping with both extremes. ▶

Tiny extremities
Bears have very small ears and tails in order to minimise heat loss.

Energy-rich diet
A diet of seals is rich in fat, providing energy for the bears to roam the Arctic all winter.

Formidable claws
The polar bear's huge claws can measure up to 5cm (2in) long, excellent for catching prey and aiding grip.

Swimming tools
In the water, a bear's huge paws act as paddles for efficient swimming.

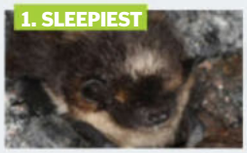
Paw pads
Small bumps called pappilae on the bear's paw pads help to aid grip on the ice.

Furry defences

During the summer when the Arctic's snow has receded, the Arctic fox's coat is a brownish hue. This camouflages the animal against the tundra and scrubland and allows it to blend in seamlessly with its surroundings. When the snow starts to fall, the fox's coat moves with the seasons and transforms into a perfect icy white. These foxes have big, bushy tails to curl up under for warmth, thick, insulating fur to keep out Arctic chills, small eyes and snouts to minimise heat loss, and even furry soles on their paws to provide grip in their wintery home.

The fox's legs are short – keeping low to the ground avoids icy Arctic winds

1. SLEEPIEST

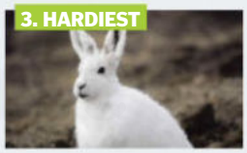


Hibernation
Winter is energy-demanding for animals, so slipping into a deep slumber is often the most effective way of staying safe and alive.

2. FASTEST

Migration
Moving from one place to another to avoid winter means animals are always in the optimum location for their needs at any time.

3. HARDIEST



Adaptation
This can come in many forms, be it physical, such as changes in coat (both thickness and colour) and metabolism, or behavioural.

DID YOU KNOW? *The Himalayan jumping spider lives 6,700m (21,982ft) above sea level – one of the highest-living species on Earth*

Polar defences

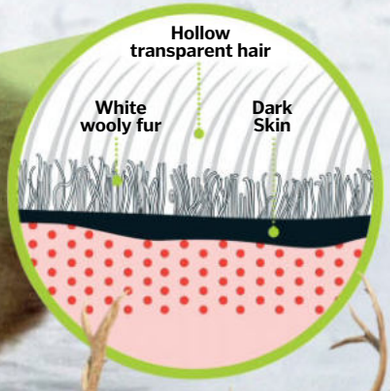
The polar bear is perfectly adapted for life deep inside the Arctic Circle

Bountiful blubber
A layer of blubber up to 11cm (4.3in) thick sits beneath the bear's skin and keeps it warm during long swims.

Life habits
Pregnant female bears will dig a snow den to escape the harsh winters and give birth to cubs.

Downy undercoat
The polar bear's undercoat is so efficient at keeping in warmth that adult bears often overheat when running!

Specialised skin
Although they appear snowy white, a polar bear's skin is actually very dark – this helps to maximise the absorption of warmth from the Sun. The hairs comprising their outer layer of fur are also hollow, trapping air for extra warmth.



Migration tactics

Caribou, more often known as reindeer, roam the Arctic tundra in large herds. Although they migrate long distances to avoid the worst of the winter, they still have a remarkable set of adaptations to keep them snug in the cold. Two very different layers of fur keep the reindeer's body warm, and their hooves are a unique shape to provide excellent balance on wintery ground. The caribou's muzzle is covered in tiny hairs, as are its nostrils, which help to warm the freezing air before it reaches the lungs. This is especially important, as the reindeer relies on its sense of smell to sniff out a meal.

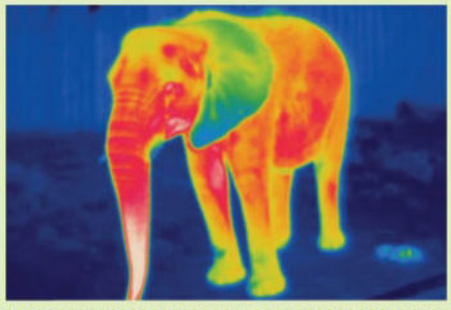
Caribou have complex digestive systems, allowing them to survive on lichens, their main winter food

Hot versus cold

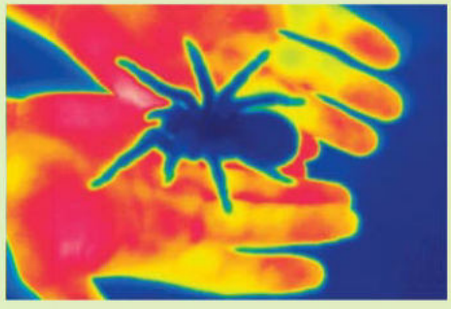
What are the benefits or being warm or cold blooded when it comes to weathering the winter?

Polar bear
This thermogram shows the temperature of heat emitted from a warm-blooded polar bear. The bear's thick fur provides such good insulation that not much heat is lost. The most heat escapes through the bear's eyes, nose and ears, which is why they have such small facial features!

Elephant
Elephants are also warm blooded, and this thermogram shows that the elephant's body (and pile of manure) is much warmer than the environment around it. The animal is emitting more heat than the polar bear – this is because it doesn't need such extreme amounts of thermal protection for life in warmer climates.



Tarantula
Unlike mammals, spiders are cold blooded. They are ectotherms, which means they use the external environment to regulate their temperature. The spider appears blue on this thermogram, much colder than the hands holding it. The benefit of being cold blooded is that the animal requires less energy to survive.



"The animals that make Antarctica their home have to be resilient, adaptive and well insulated!"

Animals of the Antarctic

Despite the sub-zero temperatures, biting winds and unforgiving terrain, Antarctic animals survive against the odds

At the very bottom of the Earth, life is tough. The animals that make Antarctica their home have to be resilient, adaptive and most of all, well insulated! Food is also key, and so many of Antarctica's residents are highly adapted for hunting, as keeping warm requires a lot of energy! Seals wrapped up in blubber are able to withstand the icy chill of the seas and many seabirds live on the richly stocked islands surrounding the South Pole, with many more visiting seasonally to breed or feed. Even the majestic emperor penguin has some incredible means of surviving the harshest of winters, serving as living proof of nature's relentless policy of 'adapt and overcome!'

Wandering albatross
At their best during rough weather, the albatross's colossal wings can lock into place for effortless gliding on the wind.

Crabeater seal
Despite their name, these seals feed on Antarctica's rich supply of krill, using specially adapted teeth to filter the water.

Elephant seal
These seals have more haemoglobin in their blood to carry more oxygen, enabling deeper and longer dives for food.

Chinstrap penguin
Densely packed feathers that insulate and also provide a protective waterproof layer help to keep these small birds warm.

Black rock cod
As cold-blooded ectotherms, ice fish possess 'antifreeze' proteins in their blood that prevent them from freezing.

Antarctic prion
Antarctica's islands support many breeding colonies of this bird, which feeds on the rich supply of fish, squid and crustaceans.

Leopard seal
A streamlined super-speedy swimmer, this seal keeps warm though rapid motion and a diet of warm-blooded critters.

5 TOP FACTS
AMAZING PENGUIN ADAPTATIONS

1 Shivering
When it gets really cold, penguins will shiver. The contracting of muscles generates heat, and so this helps to raise the bird's body temperature.

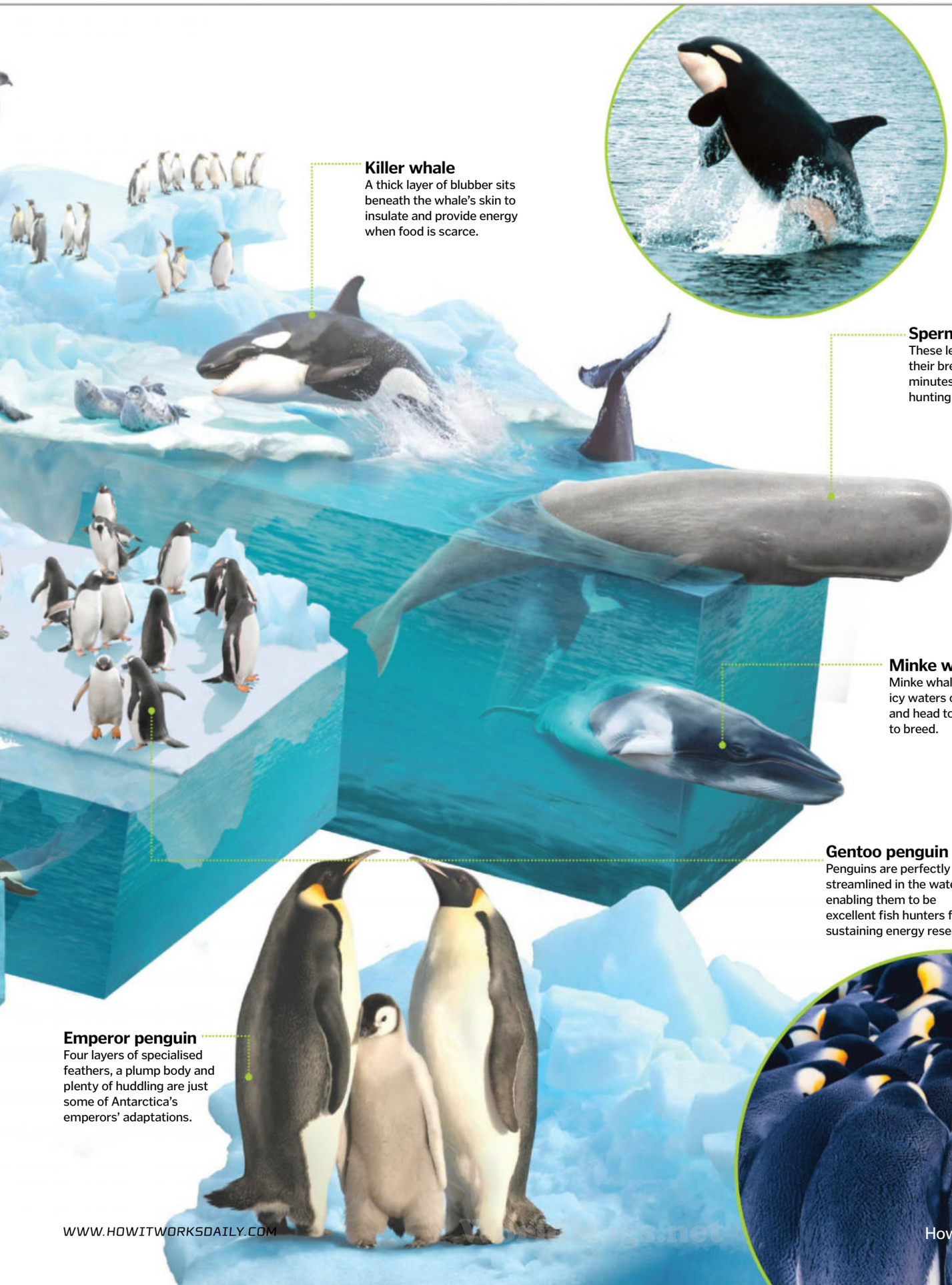
2 Happy feet
Penguins have specialised muscles that allow them to stand on tiptoes. This reduces the surface area in contact with the ice, allowing them to stay warmer.

3 Cooling down
As penguins are so well protected against the cold, if they get too hot they can increase blood flow to their feet and flippers to cool down.

4 Better together
Male emperor penguins will group together during the winter in a huge huddle to share body heat. They take it in turns to be on the huddle's outer edges.

5 Key colouring
The tuxedo style sported by penguins has a purpose – black absorbs the heat, so it is the best colour to wear when you need to preserve every scrap of warmth!

DID YOU KNOW? *Cold-blooded lizards become sluggish in cold weather; when it's warm, they're quick and fast!*



Killer whale
A thick layer of blubber sits beneath the whale's skin to insulate and provide energy when food is scarce.

Sperm whale
These leviathans can hold their breath for up to 90 minutes on deep dives hunting for giant squid.

Minke whale
Minke whales leave the icy waters of Antarctica and head to the tropics to breed.

Gentoo penguin
Penguins are perfectly streamlined in the water, enabling them to be excellent fish hunters for sustaining energy reserves.

Emperor penguin
Four layers of specialised feathers, a plump body and plenty of huddling are just some of Antarctica's emperors' adaptations.

"When it comes to staying warm, energy is everything and size really matters"

Mountain survivors

Up in the hills, it takes more than just a thick coat of fur to survive in this harsh ecosystem

High mountains provide a unique ecosystem, and with that comes a set of unique challenges for the animals that live there.

When winter falls, inhabitants have a few choices – one option is to wait out the worst of this energy expensive season and hibernate, like the marmot, which sleeps from October into April. The marmot's body temperature and heart rate drop, as the little critter conserves precious energy until the weather warms.

Other animals that stay awake through the winter will adapt their appearance. Some creatures, such as the rock ptarmigan, a chicken-sized bird found in rocky mountains of North America and Europe, changes colour for camouflage. Other animals, such as some deer species, will turn a darker colour. Although it stands out against the snow, the benefit is that darker colours retain more heat.

When it comes to staying warm, energy is everything and size really matters. Small animals need to eat much more in order to stay warm as they lose heat fast. The mountain shrew must consume its own weight in food every day just to survive the chill.

The snow cat

Snow leopards are perfectly suited to life in a mountainous wilderness

Nose
The nose is wide with an enlarged nasal cavity to heat cold air before it reaches the lungs.

Fur
A camouflaged coat of long fur with a thick, woolly undercoat keeps the cat snug in the snow.

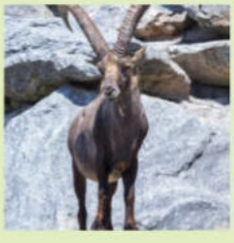
Legs
Front legs are short and back legs are long and strong to power the leopard's colossal leap.

Tail
A long, thick tail helps it balance when traversing its rocky, mountainous home area.

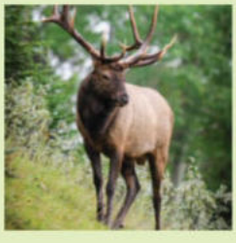
Paws
Huge, wide paws act like snowshoes, distributing its weight as it stalks over the snow.

Animal mountaineers

Alpine ibex
Thick fur and nimble sure-footedness are the things that allow the ibex to thrive in the hills. Its specialised hooves help to grip the rock as it leaps across the terrain in search of vegetation to eat.



Elk
In summer, large herds of elk migrate to the mountains to graze in western USA. When the seasons turn, they head back down the hillside into they valleys where the weather changes are much less severe.



Yak
As one of the highest-living domesticated animals, yak have thick, shaggy coats to keep them warm. They also have much larger lungs and hearts, which help them deal with living at high altitudes.

What induces hibernation?

A Eating too much food **B** Darkening days
C Hormonal changes

Answer:
A molecule known as adenosine, found in all animals – even us humans, induces hibernation. In hibernating animals, at the right time of year, this molecule is produced in large quantities and binds to receptors in the brain to induce a deep sleep.

DID YOU KNOW? *Inactivity is the best way to conserve energy, so aquatic animals may live in deeper, O_2-rich water in winter*

Desert dwellers

In a world of sandy extremes, desert animals have to withstand both freezing and scorching temperatures

Lizards
Using thermoregulation to maintain body temperature, lizards scuttle in and out of the shade to heat up or cool down.

Hares
Fur is great protection against heat and cold. Jackrabbits have fur on their soles to protect pads from hot sand.

Snake
Snakes regulate their temperature by passively exchanging heat with the air and soil.

Birds
Feathers can be fluffed up to trap air for warmth, or sleeked to greatly reduce the insulating layer.

Fox
As one of few large desert mammals to dig a burrow, foxes venture out of their dens when temperatures are optimal.

Kangaroo rat
Living in a burrow to avoid extreme heat and cold, kangaroo rats get their moisture from seeds and do not drink water.

Shrew
Idle during the heat of the day, shrews have a lower metabolic rate and adapted respiratory system for desert life.

The desert is well known for its hot, dry and dusty expanses of burning sand. Animals that live here have to deal with scorching temperatures of up to 50 degrees Celsius (122 degrees Fahrenheit) and deal with less than 250 millimetres (9.8 inches) of rainfall per year. However, the clear, cloudless conditions that heat the desert to such soaring temperatures during the day also mean that during the night, temperatures regularly drop below freezing. These extreme conditions make it a constant challenge for animals to maintain a safe body temperature and survive.

One of the best strategies to escape both the heat and the cold is simply avoidance. Many small mammals will dig burrows in the sand to create a more manageable microclimate for themselves, while cold-blooded creatures will seek out sheltered spots in crevices or shadows of cliffs. Animals that are active during the day will be out and about at dawn, when the temperatures are at their coolest, but not in the frozen grip of night.

Larger animals don't dig burrows, but having a large body is actually beneficial in the desert – it takes longer to heat up. This makes it possible to stay cool for long enough until the sun starts to set. After this, fur can be fluffed up to insulate against the chill.

The universe in your hands

All About Space™

BUY YOUR COPY TODAY

Print edition available at www.imagineshop.co.uk

Digital edition available at www.greatdigitalmags.com

Available on the following platforms

Print Tablet Phone Desktop

facebook.com/ImagineBookazines twitter.com/Books_Imagine

5 TOP FACTS
CLOUD FORMATION

1 Rising heat
When the Sun heats the ground, hot air will rise off of it in columns called thermals. These thermals can produce puffy cumulus clouds.

2 Airflow obstructions
Clouds often form around hills and mountains, as the warm air has to rise around the obstruction, which means it then cools quickly, creating clouds.

3 Converging streams
When two streams of air, flowing in different directions, meet they will be forced to converge upward together. This process can create cumulus clouds.

4 Wind turbulences
Changes in wind speed and height creates turbulences, which in turn will cause warm and cool air to meet, enabling clouds to form.

5 Fronts
Fronts separate warm and cold air. When a considerable amount of warm air rises above large amounts of cold air in a front, clouds can form.

DID YOU KNOW? *Clouds on Venus are actually composed of sulphur dioxide and drops of sulphuric acid*

Cloud-spotting guide

Find out what causes clouds to form and learn how to identify the most common types in our atmosphere

Milky cirrostratus clouds
Cirrostratus clouds cover the sky like a smooth thin veil and can create the appearance of a halo around the Sun. They form high up between 5,490-9,100m (18,000-40,000ft) and indicate that there's moisture at high altitudes.

Curling cirrus clouds
Known as mares' tails, these high-altitude clouds are thin and wispy with a distinct curved shape. They appear in small bands up to 12,190m (40,000ft) above ground and are composed of minute ice crystals.

High-flying cirrocumulus clouds
Appearing as a mass of small, thin puffs of cloud, cirrocumulus clouds develop at high altitudes between 6,100-12,190m (20,000-40,000ft) and are similar in formation to low-level altocumulus clouds. They are composed of ice crystals and supercool water droplets.

6,100m (20,000ft)

Vast altostratus cloud cover
A thin but large cover of featureless altostratus clouds develop between 2,130-5,490m (7,000-18,000ft) above Earth. They diffuse sunlight so shadows won't appear on the ground.

Layered altocumulus clouds
Altocumulus is a middle-level cloud that forms between 1,980-5,490m (6,500-18,000ft) above the ground. Its formation varies between large patchy layers and spaced out flat or wavy shapes. They consist of cool water and ice crystals and often indicate a coming change in weather.

Cumulonimbus thunderstorm clouds
Cumulonimbus clouds have low-lying dark bases that usually form between 335-1,980m (1,100-6,500ft). They are known as thunderstorm clouds and are associated with lightning, thunder, heavy downpours of rain or hail and even tornadoes!

Dense stratus clouds
Stratus clouds provide a blanket of grey or white cloud cover and can at times appear low on the ground as a form of fog. They are also usually accompanied by drizzle or snow.

Floating cumulus clouds
Puffy cumulus clouds resemble cauliflowers and their bases form up to 1,980m (6,500ft) above the ground. They are usually seen in fair weather and if they continue to grow in size, they will become thunderous cumulonimbus clouds.

2,000m (6,560ft)

Patchy stratocumulus clouds
Stratocumulus clouds spread like a shallow patchy sheet across the sky. They are low-lying clouds and are formed by shallow convective currents in the atmosphere. Their presence indicates light precipitation and they are usually seen before or after bad weather.

"Large schools of fish can also confuse an attacker by making it difficult for it to single out its prey"

Shoaling versus schooling

Discover how and why fish stick together as they travel the oceans

A group of hundreds or sometimes thousands of fish swimming in unison is one of the most spectacular sights in nature, but what is the reason for this incredible phenomenon?

First, it is important to understand the subtle difference between shoaling and schooling. A shoal is a social group of fish swimming closely together but foraging for food individually. Those shoals can consist of different species and sizes of fish. A school of fish swim in a more synchronized fashion, moving at the same speed and turning simultaneously. These groups often consist of a single species.

Some species, including tuna and herrings, are obligate shoalers, meaning they spend all of their time either shoaling or schooling. Others, such as Atlantic cod, will only shoal some of the time, often when they are looking for a mate.

In addition to reproduction, there are several other reasons why fish congregate in shoals or schools. One is that it gives them the advantage of safety in numbers, as being part of a group reduces the chance of a fish being eaten by a predator. Large schools of fish can also confuse an attacker by making it difficult for it to single out its prey or even scare the predator off by resembling one large fish.

Another benefit is that several eyes are better than one, and so a shoal of fish is much quicker at spotting food or a potential predator than one fish is on its own.

Scientists also believe that swimming in unison gives the fish more hydrodynamic efficiency, as the beating of the front fish's tail helps to propel those in its wake.

How do herrings communicate at night?

A Farting **B** Singing **C** Morse code

Answer:
Herrings communicate with the rest of their school at night by breaking wind. They create high-frequency sounds and a stream of bubbles by releasing air from their anuses, informing other fish of their whereabouts.

DID YOU KNOW? *Shoaling reduces stress, as a solitary fish's heart rate is often much faster than that of a fish in a shoal*

Fast-moving schools typically form a wedge shape, while feeding schools are usually circular

How fish swim in unison

Schools of fish move very quickly and can change direction at a moment's notice, yet the fish manage to never break formation or collide. Their fast reaction speed allows them to instantly copy the movements of the fish next to them, which they can see thanks to the position of their eyes on the side of their head.

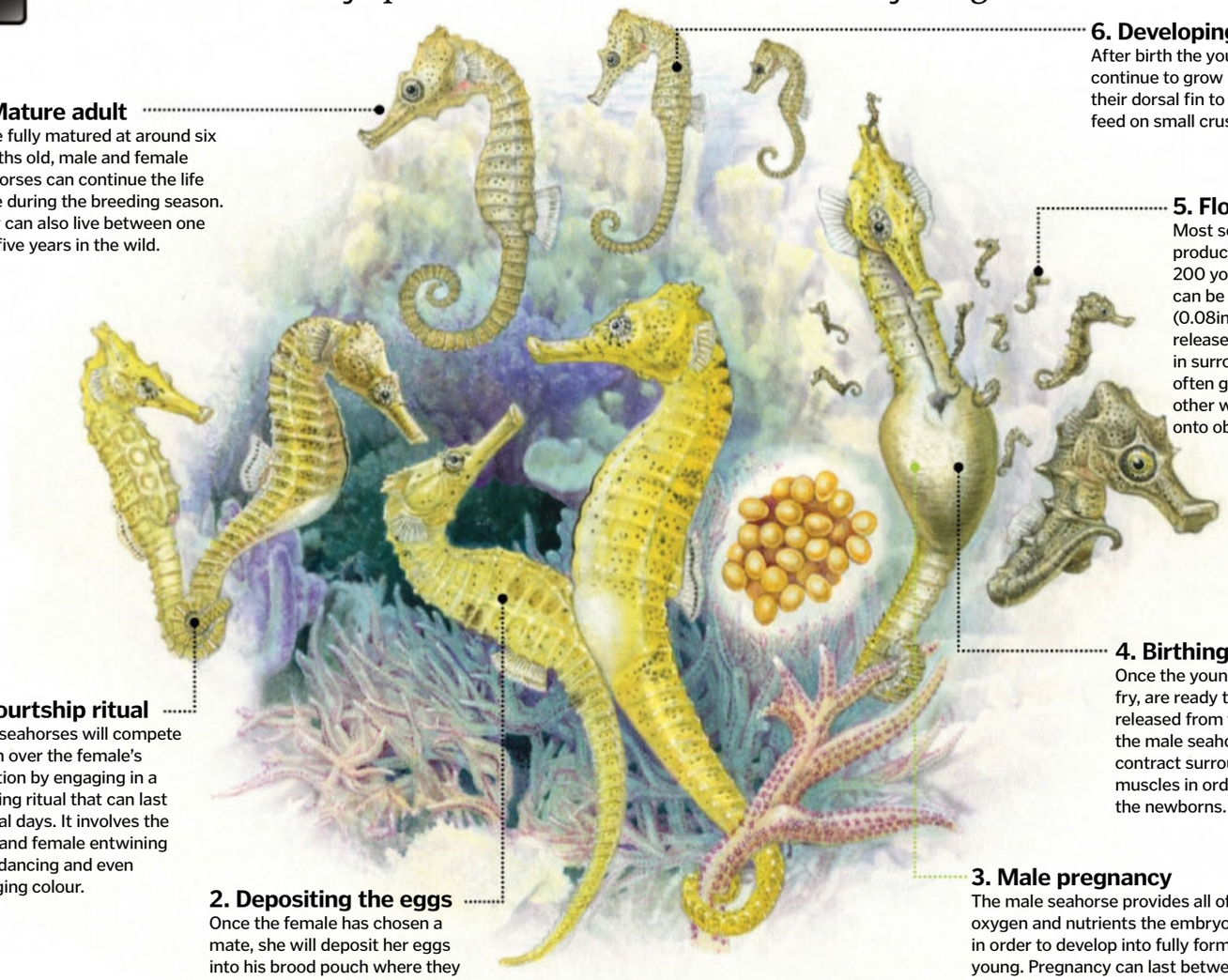
Vision plays a big part in a fish's ability to school, as most schools become shoals when it gets too dark to see. However, many species of fish also have a lateral line down the side of their body, which contains cells similar to the hair cells found in the human ear. This enables the fish to sense changes in water currents, helping them to detect the movements of nearby fish when visibility is poor and keep a safe distance from them as they change speed and direction.

A shoal, such as this group of oriental sweetlips, has a loose formation

"Most seahorse species produce around 100 to 200 young, and they can be as small as 2mm (0.08in) long"

Life cycle of a seahorse

Learn about the only species where the male bears the young



1. Courtship ritual
Male seahorses will compete to win over the female's affection by engaging in a courting ritual that can last several days. It involves the male and female entwining tails, dancing and even changing colour.

2. Depositing the eggs
Once the female has chosen a mate, she will deposit her eggs into his brood pouch where they will be fertilised by his sperm and then embedded into the spongy pouch wall.

3. Male pregnancy
The male seahorse provides all of the oxygen and nutrients the embryos need in order to develop into fully formed young. Pregnancy can last between two and six weeks, depending on the surrounding water temperature and species of seahorse.

4. Birthing process
Once the young, known as fry, are ready to be released from the pouch, the male seahorse will contract surrounding muscles in order to expel the newborns.

5. Floating fry
Most seahorse species produce around 100 to 200 young, and they can be as small as 2mm (0.08in) long. Once released they will float in surrounding water, often grasping to each other with their tails or onto objects nearby.

6. Developing juvenile
After birth the young seahorse will continue to grow in size. They use their dorsal fin to swim and will feed on small crustaceans.

7. Mature adult
Once fully matured at around six months old, male and female seahorses can continue the life cycle during the breeding season. They can also live between one and five years in the wild.

The snake that plays dead

The hognose snake dramatically defends itself from predators

The hognose snake, distinguishable by its upturned nose, is one resourceful reptile. This shrewd serpent will feign death when its display of aggression fails to unnerve a predator.

When threatened, the snake will first replicate the behaviour of a cobra, by puffing out its body while raising its head and flattening its neck to hiss. But if that doesn't deter a predator, some hognose snakes will actually roll onto their backs and play dead!

This convincing charade involves dramatically writhing their body as if in pain before lying still and emitting a foul odour. They will even go as far as opening their mouths so that their tongue hangs out, and have been known to regurgitate their last meal.

What's more, they will keep up the pretence until they're convinced the threat has gone. So if you were to roll the snake's limp body onto its front, it will immediately return to its dramatic death position.

The hognose snake will roll onto its back and theatrically feign death to deter predators

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

The Apollo 4 launch in 1967, the first from Florida's Kennedy Space Center

How close are you allowed to get to a rocket launch?

Dave Brown

Depending on the agency launching the rocket, you can usually get quite close to a launch. For example, you can view a NASA rocket launch at Kennedy Space Center from the Apollo/Saturn V Centre viewing area, which sits about five kilometres (three miles) from its world-famous launch pad. The ESA launches its rockets from its own spaceport, Centre Spatial Guyanais in French Guiana. There is limited viewing space, however, and in the case of NASA launches, you have to buy a ticket. **SF**

Why don't touchscreen phones work with gloves on?

Rachel Cartwright

Most modern touchscreens use capacitive sensing. This uses two glass layers, coated on their inside surfaces with stripes of a transparent conducting material called indium tin oxide. On one layer the stripes run horizontally and on the other layer they run vertically. Each intersection acts as a tiny capacitor that stores an electric charge. When you touch the glass, your finger distorts the electric field and changes the amount of charge the capacitors underneath it can hold. But this only works because your finger conducts electricity. With gloves on, your fingers are insulated and don't distort the electric field. Special touchscreen gloves use electrically conductive thread woven into the fingertips. **LV**

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in Zoology from Oxford University and another in Real-time Computing. He has been writing about science and technology since before the web was invented. His sci-fi novel *A Jar of Wasps* is out now.

Sarah Bankes

Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Alexandra Cheung

Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

Laura Mears

Laura studied biomedical science at King's College London and has a masters from the University of Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

A silencer is a tube of small chambers separated by baffles

How does a silencer on a gun work?

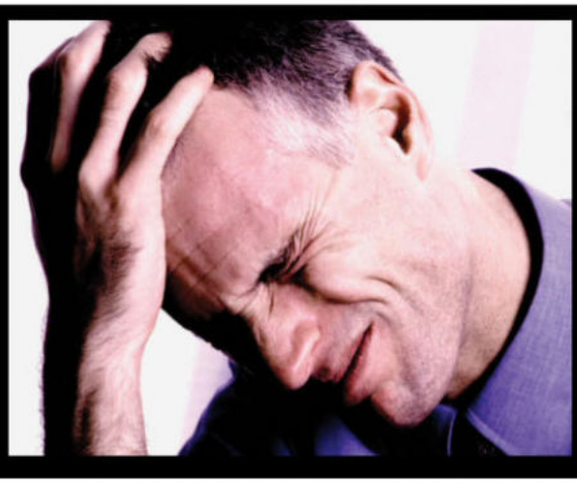
Denise Crossley

When a gun is fired, explosive gunpowder is ignited. The explosive creates a high-pressure pulse of hot gases, which forces the bullet down the gun barrel. It exits like a cork leaving a champagne bottle, but at a supersonic speed with a bang that breaks the sound barrier. A gun silencer suppresses that sound. The suppressor consists of a tube of small chambers separated by baffles, attached to the end of the barrel. When the gun is fired, the pressurised gas now has lots of holes to expand into, so the pressure is far lower when the bullet exits the barrel, lowering the sound. **SB**

How do painkillers work on the body?

Sandra Ray

You feel pain when tissue is subjected to damage and releases chemicals called prostaglandins. These stimulate specialised nerves, sending a signal to the central nervous system and on to the brain. Painkillers can stop the signal to prevent it from reaching the brain. Non-opioid analgesics such as aspirin or paracetamol prevent damaged tissue from releasing prostaglandins. Opioid analgesics such as codeine or morphine bind to opioid receptors in the brain and spinal cord, preventing pain signals from being passed on. **AC**



What animal has the most powerful bite?

Hannah Burton

Bite force is partly about raw size, but it also has a lot to do with the shape of the jaw and the position of the muscles. Bite force hasn't been measured directly for every known animal, but those we have measured allow us to estimate the bite force of the others, simply by measuring their skulls. Humans bite with a force of about 890 Newtons (200 pounds force), while lions and tigers bite five times harder at 4,450 Newtons (1,000 pounds force). At the top end, saltwater crocodiles' bite is almost four times harder again at 16,460 Newtons (3,700 pounds force). **LV**

Why do cheese and butter turn yellow?

Tom Alworthy

We all know that cheese and butter come from milk and that milk comes from cows. But did you know about the fat-soluble yellow pigment and antioxidant found in grass, known as beta-carotene? Believe it or not, it's this grass-dwelling antioxidant that's responsible for the yellow colour in cheese and butter. Once a cow has chewed the cud, this antioxidant dissolves into the cow's fat stores and ends up in milk. Its colour is hidden in milk by protein clusters and fat-surrounding membranes, but these clusters and membranes weaken during the cheese-making process, and the yellow pigment is released. **SB**

FASCINATING FACTS

Anglerfish use bacteria to light their antennae

The 'fishing rod' of the female anglerfish contains millions of symbiotic bacteria, which synthesise glowing compounds called luciferins. Their prey are attracted to the light so the anglerfish lures them in and gobbles them up.

What makes gold so sought after? Find out on page 82

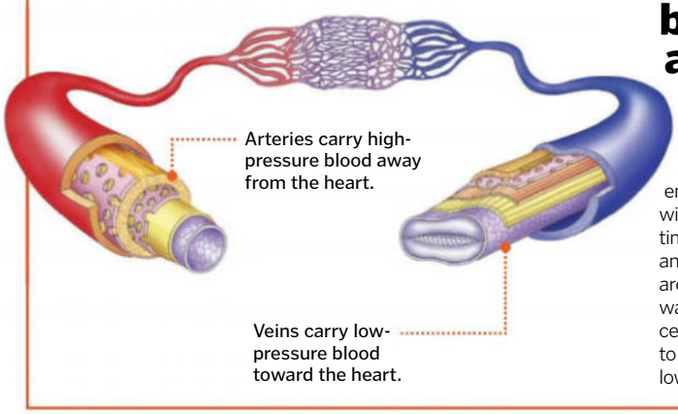
BRAIN DUMP

Gold has been used as a currency by cultures across the globe

Why is gold so valuable?

Robin Bright

Gold has been prized throughout human history due to its scarcity, combined with a unique selection of properties that led to its use as a currency. Gold is rare, making up just five parts per billion of the Earth's crust. It is also difficult and expensive to extract, and so only very limited quantities can be mined every year, making it a stable currency. Gold is remarkably unreactive and so does not oxidise like silver or iron. Therefore, gold coins do not lose or gain weight over time. While other metals such as aluminium, platinum or silver look quite similar, gold is the only yellow metal, rendering it instantly recognisable. Gold's attractive appearance has also made it a popular material for jewellery and other adornments. Gold's malleability allows it to be moulded into different shapes and divided easily. **AC**



Is there any difference between veins and arteries?

Lisa Cornish

In order to withstand the high pressure as the heart beats, arteries need to be thick and muscular. They resist stretching, helping to maintain enough pressure to push blood around the body without bursting under the strain. However, by the time the blood has travelled through the capillaries and into the veins, the pressure is much lower. Veins are wider in internal diameter than arteries, and their walls are thinner, allowing them to store up to 70 per cent of the blood in the body as it makes its way back to the heart. One-way valves help to keep the low-pressure blood travelling in the right direction. **LM**

FASCINATING FACTS

Not many have won multiple Nobel Prizes

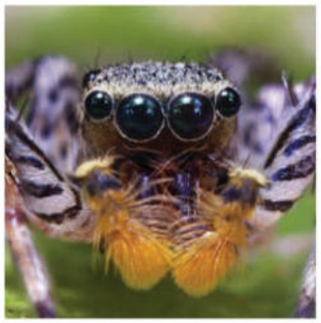
Only four people have won more than one Nobel Prize: Marie Curie, Linus Pauling, John Bardeen and Frederick Sanger. The International Committee of the Red Cross and the United Nations High Commissioner for Refugees have also won it more than once each.

The golf ball has landed

Apollo 14 astronaut Alan Shepard famously hit two golf balls on the Moon, using a golf club head that he attached to the handle of his lunar excavation tool. Due to the Moon's low gravity, they flew much further than they would have on Earth.

Crete was home to history's longest siege

The Siege of Candia in Crete lasted for an incredible 21 years. The invading Ottomans surrounded the city with 60,000 troops in 1648, but not until 1669 did the persistent inhabitants surrender.



Why aren't spiders classed as insects?

Jon Butterfield

Insects and spiders are both arthropods with a chitin exoskeleton and segmented bodies, but the fossil record shows that their evolutionary trees separated around 420 to 450 million years ago. Insects all have six legs and three body segments: head, thorax and abdomen. They have a pair of antennae on the head and sideways-moving mandibles for grasping and chewing. Spiders have just two body segments: cephalothorax and abdomen. They don't have antennae and instead of mandibles they have hollow fangs, called chelicerae, that stab downward to inject venom. The differences between spiders and insects are as big as the difference between birds and mammals. **LV**

What is dust made of?

Tyrone Mullarky

The composition of dust depends on where the dust is located and the habits of the people who live there. There's a myth that most dust inside your house primarily comprises flakes of shed human skin, but that's not true. Most of your skin flakes go down the drain when you wash. Dust does have some nasty bits in it, though. There's some skin, granted, but there can also be hair, animal dander and fur, soil, dead insects and their faeces, sand, food particles, pollen, bugs, fibres from clothing and linens, pollution and soot. **SF**

Selective hearing is not necessarily a bad thing

Is selective hearing a real medical condition?

Olive Johannson

When we utter the words 'selective hearing', it is often in jest, as we tend to associate the concept with someone ignoring us because we are saying something they don't particularly want to hear. However, many of us practise selective hearing on a daily basis. When we have a conversation with someone in a loud environment, the ability to filter out other voices and sounds around us is selective hearing in practice. Scientists from the University of California, San Francisco, discovered the auditory cortex in the brain enables us to do this, as it cleverly copes with conflicting sounds. **SB**

How can some animals hear really high or low sounds?

Lee Grant

Mammals generally have a wider hearing range than other animals because they have a longer ear canal, coiled into a spiral called the cochlea. Human hearing ranges from about 20Hz to 20kHz, but bats use frequencies up to 160kHz for echolocation and they have several adaptations to let them hear sounds at this pitch. Their outer ears are much larger, with lots of folds to help channel sound inward. Their cochlea is also huge, up to a third of the skull's size. The sensory hairs are shorter, so are tuned to higher frequencies. At the low-frequency end, elephants, turtles and some flatfish can detect sounds as low as 10Hz, so low that sound is felt more than heard. Elephants use the soles of their feet for this and fish use a vibration-sensing lateral line, rather than their ears. **LV**

How far away from the galactic edge is Earth? Find out on page 84

BRAIN DUMP

Why is Antarctica a continent but the Arctic isn't?

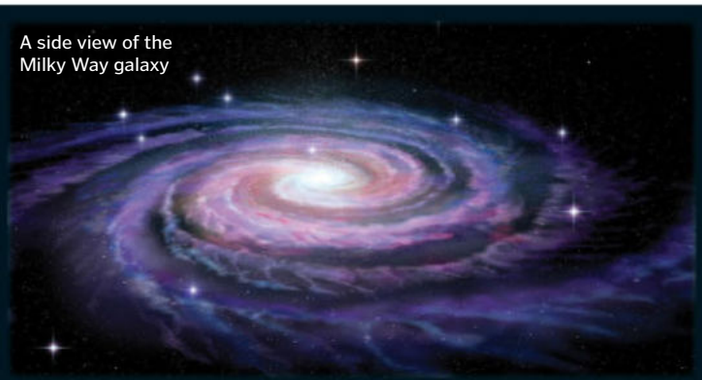
Paul Gerano

On the surface, the Arctic and Antarctic seem quite similar, but if you were to look beneath the ice and snow, you would find that they are very different. A continent is defined as a large, mostly continuous expanse of land, and although Antarctica is covered by a thick ice shelf, if you melted through it, it would reveal rocks, valleys and mountains. Antarctica is a landmass greater in size than both Europe and Australia, making it the fifth-largest continent on the planet. If you did the same to the Arctic and removed the ice and snow, all that would be left is the Arctic Ocean, as there is no land hiding beneath. So while Antarctica is a continent surrounded by water, the Arctic is water surrounded by three continents; Europe, Asia, and North America. **LM**

FASCINATING FACTS

Hot water can freeze faster than cold

A number of mechanisms are believed to be responsible for this intriguing reality, including the fact that as hot water evaporates there is less water left to freeze.



A side view of the Milky Way galaxy

Where is the edge of the galaxy?

Billy Somersby

Galaxies don't have exact boundaries, but ours has an approximate diameter of 100,000 to 120,000 light years and a thickness of about 1,000 light years. It is a barred spiral galaxy, and our Solar System is located at the edge of one of its four arms, a smaller spur called the Orion-Cygnus Arm. The rotational centre of the Milky Way is called the Galactic Centre, and our Solar System orbits it at about 250 kilometres (155 miles) per second, taking 200 to 250 million years to complete one orbit. Our Solar System is about 25,000 light years from the Galactic Centre. It's also estimated to be about 25,000 light years from the rim of the Milky Way, so that puts us about halfway to the edge of it. **RS**

How are rechargeable batteries different from regular ones?

Luke Masterton

All batteries use the same type of chemical reactions to generate an electrical current, but in rechargeable batteries this reaction is reversible. Inside a battery, a variety of chemicals can be paired to produce a reaction resulting in a flow of electrons. Rechargeable batteries use a pair of reactants that allow the reaction to be reversed. Inside a nickel-cadmium battery, NiOOH and Cd are used up as they react to form $Cd(OH)_2$ and $Ni(OH)_2$. Applying an opposite electrical potential allows these products to be converted back to the original reactants. **AC**

A comet travelling across the sky

What's the difference between a comet and an asteroid?

Charlotte Galloway

Asteroids and comets orbit the Sun and are leftovers from the formation of our Solar System. Both are also irregularly shaped and occasionally crash into Earth. Comets are mostly ice, and can big as 40 kilometres (25 miles) across. They form in the outer Solar System. Asteroids are rocky and larger; they can range from particle-sized to 1,000 kilometres (620 miles) across or more and come from the Asteroid Belt. Comets partially melt and form tails as they get closer to the Sun, but asteroids are solid and stable. And while there are millions of asteroids, there are only about 4,000 known comets. **SF**

Why don't fire-eaters burn themselves?

Shane Johnson

The truth is that they do sometimes burn themselves, but overall, the risk is about the same as drinking a hot cup of coffee. The idea with fire-eating is to close your mouth entirely around the flame, cutting off the supply of oxygen, causing the fire to go out. The fire only lives a few seconds and the saliva coating the mouth helps protect it from burns by absorbing some of the heat before it gets to the membrane underneath. They also often drink fatty liquids like milk or cream beforehand to further coat the mouth's inside. **LM**

Matches contain sulphur, which is necessary for them to catch fire

How can a match light up?

Vanessa Li

The friction created when you strike a match triggers a series of chemical reactions, causing it to ignite and then combust. To produce a flame, you need something to burn (fuel), oxygen and enough heat. The match head contains sulphur, glass powder and an oxidising agent. Meanwhile, the striking surface is made of sand, powdered glass and red phosphorus. The heat generated when you strike the match converts some of the red phosphorus into unstable white phosphorus, which spontaneously ignites. This starts a chemical reaction, allowing the oxidising agent to produce oxygen. The presence of heat and oxygen allow the sulphur to combust, creating a flame. **AC**

How do the zoom functions on cameras really work?

Edwin Mountford

A key parameter of a camera lens is the focal length, which is the distance between the lens and the plane where the image is formed. The further the distance between the lens and the image plane, the longer the focal length. An effect of different focal lengths is magnification. A zoom lens consists of many lenses comprising two types: concave and convex. The concave lens controls the dispersal of light rays entering the front of the lens, while the convex lens collects the light, focusing the rays to ensure a sharp image. The separate elements of the lens can be moved relative to each other, which is what alters the magnification or 'zoom.' **SB**

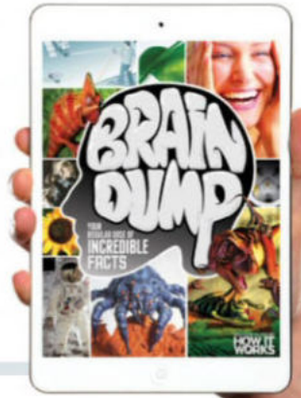
Why is rubber so stretchy?

Alexander Godov

The stretchiness of rubber is down to its structure, and the law of entropy. Rubber is made from long chains, which in their relaxed state can be twisted and curled around each other in a huge number of different ways. As it is stretched, the chains straighten out and line up, forming an orderly structure. When the stress is removed, the strands want to return to a lower-energy disordered state, so they spring backward. In many types of rubber, the strands are joined together by chemical bonds that form cross links, fixing them into a flexible web and encouraging the material to spring back to a similar shape each time. **LM**

New Brain Dump is here!

Don't miss issue 20 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 1 January. You'll learn all about deadly snake venom, why your stomach rumbles when you're hungry and how parrots can talk. Every issue is jam-packed with incredible photos and loads more trivia snippets for you to get stuck into, giving you the knowledge hit you need without having to lug an encyclopaedia around! Download the new issue of **Brain Dump** on the first day of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is @BrainDumpMag.



Get in touch

Facebook How It Works magazine

Twitter @HowItWorksmag

Email howitworks@imagine-publishing.co.uk

Fitness tech

How It Works tests the top tech for workouts

To help you make your workout session less of a chore, we've rounded up the best new fitness gadgets. From smartwatches that will plot your cycling route and monitor your heart rate to sensors that analyse your golf swing, there's something to benefit everyone.

Checklist
- ✔ Training computer
- ✔ Golf-swing analyser
- ✔ Trainers
- ✔ Scales
- ✔ Wrist strengthener
- ✔ Runner's GPS
- ✔ Heart-rate monitor

1 Comfort fit
Saucony Triumph ISO
£125 / $150
www.saucony.com
These are the most comfortable trainers we have ever worn. It moulds to your contours and the mesh covering keeps your feet cool. The heel contains shock-absorbing technology and feels rock steady and secure, while only weighing 255 grams (nine ounces). The finishing is a tiny bit messy in places, though.
Verdict: ●●●●●

2 Running mate
TomTom Runner
£159.99 / $199.99
www.maplin.co.uk / www.tomtom.com
TomTom has entered the running market with a smart-looking runner's watch. The large, clear display shows your total mileage and current speed, while the heart-rate monitor is unobtrusive and easy to put on. However, the buttons are a bit small to use while running and that caused a few problems.
Verdict: ●●●○○

3 Step counter
Pulse O$_x$
£99.95 / $119.95
www.withings.com
This device tracks many vital fitness statistics. Whether it's in your pocket, on your wrist or clipped to your waistband, the Pulse measures your heart rate, steps taken, calories burned and many more. The associated app helps you keep track of your progress. We wish the display wasn't sideways, though.
Verdict: ●●●●○

4 Golfing coach
Zepp golf-swing analyser
£129.99 / $149.99
www.pcworld.co.uk / www.zepp.com
Every aspiring Rory McIlroy who doesn't fancy employing an instructor could benefit from this. The tiny sensor clips onto your glove and analyses every aspect of your swing, from the speed to the angle of your club. The sensor is unobtrusive, accurate and you can spend ages poring over every stat, which is great fun.
Verdict: ●●●●●

Body analysis
Indium tin oxide-coated electrodes pass a current through your body to measure your body composition.

5 Smart scales

Fitbit Aria scales
£99.99 / $129.95
www.fitbit.com
These next-generation scales take weight management to a new level. Connect it to your Wi-Fi and set up an account. Aria can then track your weight, calorie intake, fluid intake, recent exercises and put together a meal plan. The scales are incredibly accurate and setting up an account is done in minutes.
Verdict: ✪✪✪✪✪

6 Cycling companion

Polar V800 sports watch
£399.50 / $519.95
www.polar.com
This multi-sport watch finds its true calling in developing cycling routes. Website registration lets you design a route and sync it with your V800. The watch provides directions, exercise time and heart rate during the cycle before uploading it to the website for analysis. GPS signal lags a little, though.
Verdict: ✪✪✪✪✪

7 Forearm fitness

Powerball 280Hz Pro
£24.99 / $39.99
www.powerballs.com
This may seem like a fun toy at first glance, but it has a genuine practical application as it helps people with repetitive strain injury (RSI). The gyroscope inside the powerball creates a resistance you have to counteract with timing and strength. The starting mechanism can be frustrating but it certainly gives your forearms a workout.
Verdict: ✪✪✪✪✪

Autostart
Models in the Autostart range contain a clutch that removes the string-pull start.

Share the wealth
Other Polar users can see your training routes and add them to their favourites.

EXTRAS

Everything you want to get cooking

BOOK

Cycling Science: How Rider and Machine Work Together

Price: £16 / $30
Get it from: **www.amazon.co.uk / www.amazon.com**
If your relationship with cycling is more than hopping on your bike for your commute, this should fascinate you. Cycling Science delves into the physics, biology and technology of cycling in an interesting, informative and engaging way.

APP

Strava

Price: Free
Get it from: **www.itunes.com / play.google.com**
If you don't fancy splashing out on a fancy watch, download this free app that uses GPS to track your cycle. It will then upload your sector times, elevation and other stats to the website for endless analysis.

WEBSITE

TheActiveTimes.com

Informative, well put together and varied, *The Active Times* offers the readers a wealth of content for all your outdoor pursuits. It provides regular expert tips for everything from marathons to surfing as well as tech reviews.

Headphones

We test out some of the best luxury headphones on the market

Brilliant battery
The lithium-ion battery takes 2.5 hours to charge but delivers six to 18 hours depending on enabled modes.

HOW IT WORKS EDITOR'S CHOICE AWARD

1 Parrot Zik 2.0

Price: £299 / $399
Get it from: www.amazon.co.uk
If you are a fan of technology you will love the Parrot Zik 2.0 headphones as they are loaded with jaw-dropping features. The accompanying app allows you to remaster tracks by changing the equalisation, so you can create the perfect musical balance. Another great feature is the Concert Hall effect. The Digital Sound Processor can manipulate the sound so the music could appear to be playing in a concert hall. It really works and, with your eyes closed, you could feel like you're in the Sydney Opera House. One of our favourite features, however, has to be the touch-sensitive control. A vertical swipe on the right earphone changes the volume and a horizontal swipe skips a track. This works really well and makes the Zik 2.0 easy to manage. They are very comfortable, fitting over the entire ear in a snug but non-restrictive way, look stylish and deliver excellent sound quality. If you hook it up to your phone via Bluetooth you can even take phone calls, which is really cool. Your voice doesn't come out as well as it probably should, but as this is something of a bonus feature it isn't really a make-or-break issue.
Verdict:

2 Bowers & Wilkins P5

Price: £249.99 / $299.99
Get it from: www.selfridges.com / www.amazon.com
If you're looking for an eye-catching, unique-looking pair of headphones, look no further than the P5. The rectangular earpads fit superbly and definitely stand out from the crowd. Not only that, but they are so spectacularly soft you can comfortably wear them for long stretches at a time. The padding does make your ears rather warm, though.

The audio quality is top notch. The bass is so good it feels you've got a pair of mini speakers rumbling on your ears. We also ran a surround sound test and the P5 passed with flying colours, providing an almost cinema-like quality to the audio helicopter buzzing around our head. We were also impressed that at even high volume, no noise seeped out, so your music won't annoy any fellow bus users. Two minor quibbles are that, for the price, it's a shame they don't include active noise-cancelling technology, and the cable could be longer. If you were watching a film you would need to be quite close to the TV.

Stylish, comfortable and an excellent music player, they feature (mostly) everything you want in a pair of luxury headphones.
Verdict:

Drop that bass
The P5's range is 10Hz to 20kHz, the entire range of our hearing spectrum.

App attack
The associated app brings up lyrics to the song you're listening to.

3 Denon Urban Raver AH-D320

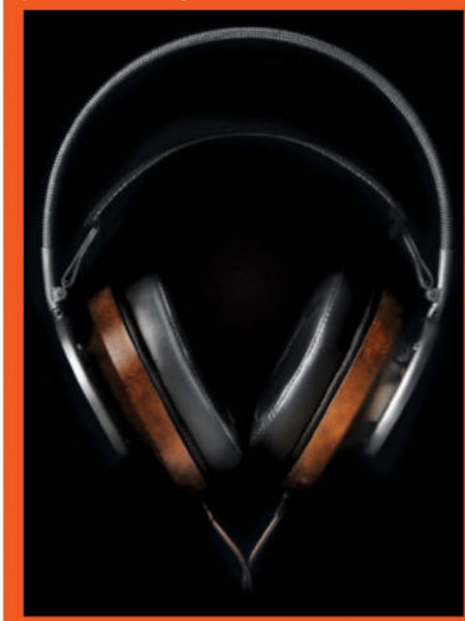
Price: £109.95 / $219.99
Get it from: www.simplyelectronics.net / www.amazon.com
Denon has gone all-out to design a pair of headphones for the hardcore bass enthusiast and has managed that, but possibly at the expense of those who don't want their head rattled inside their headphones. Dubbed the 'Urban Raver', the D320 rumbles when you're playing a low-bass track and it does interfere if the artist has a low voice as well, but other sounds build over the top well and you get a real sense of individual instruments playing, rather than the all-in-one sound delivered by some headphones. The bass can get a little too much at times, so it would be nice to have a control that reduces that level should you wish. The audio controls are on the right headphone, operated by a nicely responsive wheel, but as it only goes down by a notch per twist, rapid noise reduction is not an option. The earpads are soft but do press more firmly on the ears than we would have liked. This is a solid pair of headphones for those of you that enjoy the bass cranked right up, but better sound quality can be found elsewhere.
Verdict: ●●●○○

ON THE HORIZON

Some more incredible sound devices on their way

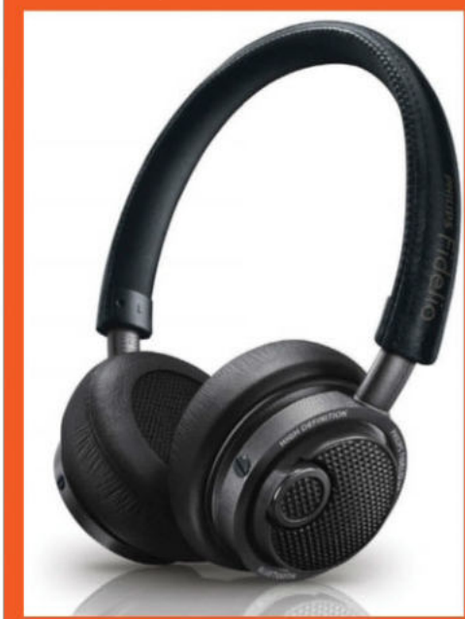
AudioQuest NightHawk

3D printing has reached the audio industry with the world's first set of headphones containing 3D-printed parts. We'd love to get our ears on them.



Philips Fidelio M2L headphones

It's what the world has been waiting for – the first pair of headphones with a Lightning connector. It's launched in Europe with a US launch soon.



© AudioQuest; Philips

EVERY ISSUE PACKED WITH...

- Fascinating facts
- Incredible photos
- Insightful features
- Latest gadget reviews
- Amazing illustrations
- Your questions answered
- Mind-blowing science and tech

WHY YOU SHOULD SUBSCRIBE...

- **Save 25%** off the cover price – **just £9 every three issues** on Direct Debit
- **FREE delivery** direct to your door
- **Never miss an issue**

ORDER BY 28TH FEBRUARY

Use code **PQ15** for this offer

BY POST

Send your completed form to:
How It Works Subscriptions, 800 Guillat Avenue, Kent Science Park, Sittingbourne, Kent ME9 8GU

YOUR DETAILS

Title_____ First name_____

Surname_____

Address_____

Postcode_____ Country_____

Telephone number_____

Mobile number_____

Email address_____

DIRECT DEBIT PAYMENT

☐ **UK Direct Debit Payment**

I will pay just £9 every 3 issues

Instruction to your Bank or Building Society to pay by Direct Debit

DIRECT Debit

Please fill in the form and send it to: Imagine Publishing Limited, 800 Guillat Avenue, Kent Science Park, Sittingbourne, Kent, ME9 8GU

Name and full postal address of your Bank or Building Society

To: The Manager — Bank/Building Society

Address

Postcode

Name(s) of account holder(s)

Branch sort code

Bank/Building Society account number

Originator's Identification Number: 5 0 1 8 8 4

Reference Number

Instructions to your Bank or Building Society
Please pay Imagine Publishing Limited Direct Debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit guarantee. I understand that this instruction may remain with Imagine Publishing Limited and, if so, details will be passed on electronically to my Bank/Building Society

Signature(s)

Date

Banks and Building Societies may not accept Direct Debit instructions for some types of account

A6 instruction form

PAYMENT DETAILS

YOUR EXCLUSIVE READER PRICE, 1 YEAR (13 ISSUES)

☐ **UK £41 (Save 20%)** ☐ **Europe – £50** ☐ **World – £60** ☐ **USA – £50**

Cheque

☐ I enclose a cheque for £_____

(made payable to Imagine Publishing Ltd)

Credit/Debit Card

☐ Visa ☐ Mastercard ☐ Amex ☐ Maestro

Card number

Expiry date

Issue number ☐☐ (if Maestro)

Signed _____

Date _____

Please tick if you do not wish to receive any promotional material from Imagine Publishing Ltd by post ☐ by telephone ☐ via email ☐

Please tick if you do not wish to receive any promotional material from other companies by post ☐ by telephone ☐ Please tick if you DO wish to receive such information via email ☐

TERMS & CONDITIONS

Terms and Conditions: This offer entitles new UK direct debit subscribers to pay only £9 every 3 issues. New subscriptions will start from the next available issue. Offer code PQ15 must be quoted to receive this special subscription price. Details of the Direct Debit guarantee are available on request. This offer expires 28 February 2015 . Imagine Publishing reserves the right to limit this type of offer to one per household. Subscribers can cancel this subscription at any time.

Get in touch

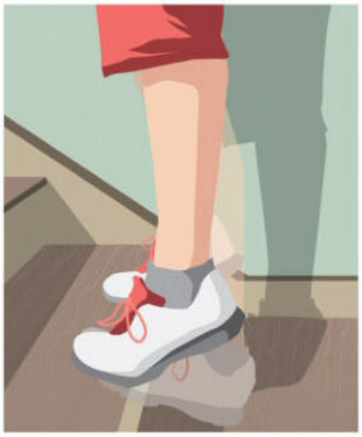
Want to see your ideas on this page? Send them to...

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

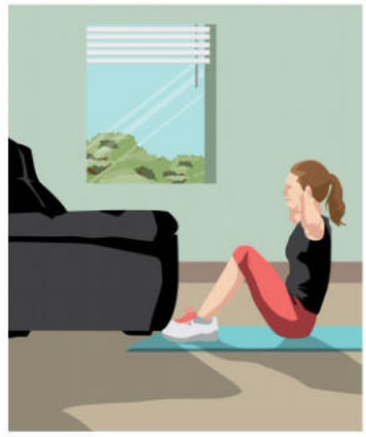
Exercise at home

Five ways you can work out without going to the gym



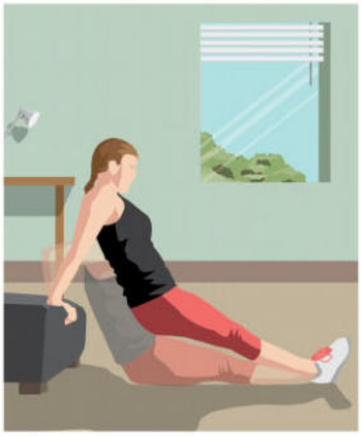
1 Stair step machine

Your calf is the part of your leg responsible for raising your heel as you walk, so training up your calves will make the walk – or desperate sprint, depending on how late you are – to the station much easier. Stand on the bottom step, facing upstairs with only your toes and the balls of your feet on the step. Push up with your toes until you're on tip-toes, then relax them down again. Repeat as often as possible.



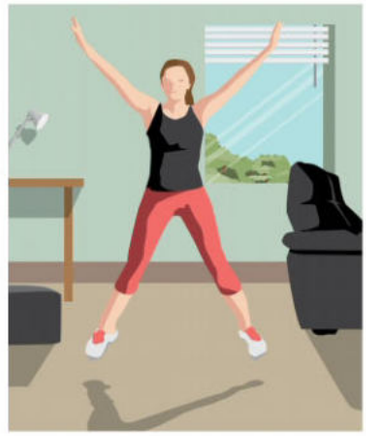
2 Trim your tummy

Your abdominal muscles form the core of your body and provide you with stability, strength and control. Strong abs will also help you with your posture by holding your upper body in position. Sit-ups are easy to do in a confined space. Wedge your feet under a sofa to keep them stable on the floor and curl your torso up toward your knees. To increase the difficulty, you can hold a weight on your chest.



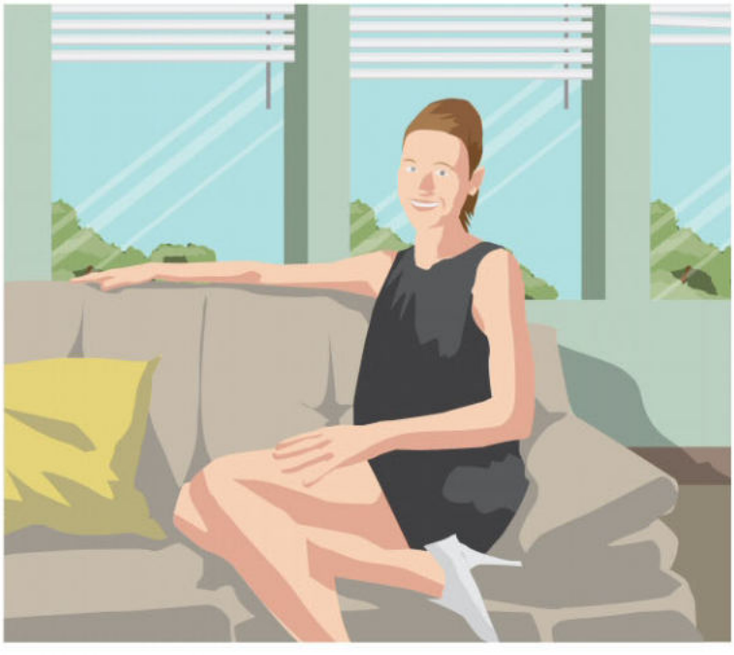
3 Toned arms

The main cause of the dreaded 'bingo wings' is fat around the triceps, the muscles on the underside of your arm. An effective way to tone up this area is a move called the tricep dip. Find a sturdy, stable surface such as a stair or low table that can take your weight. Face away from it and grip the edge with your arms straight without locking your elbows. Bend your elbows 90 degrees, straighten and repeat.



4 Add some intensity

Jogging can be tedious, but there is a scientific way to speed up your fat burning. Jog on the spot for two minutes then explode into life for 30 seconds. This could either be upping your pace, launching into some quick-fire star jumps or dropping down into a squat thrust. This short burst of intense exercise forces your body to work very hard, increasing your metabolism and encouraging fat burn in a very time-efficient way.



5 Wriggle around

If you want to sit down and watch your favourite show then go ahead and do it, but you can still burn calories in the meantime. You can burn up to 350 extra calories each day just by fidgeting and moving about while sitting down. Do this by repeatedly tensing and untensing your muscles, changing position regularly and ensuring that at least one part of your body is moving at all times.

In summary...

This should demonstrate just how easy it is to keep fit and trim without having to haul yourself to the gym. Keeping active will burn calories and as long as you are giving yourself a whole-body workout and eating healthily, you should notice rapid results, while saving your hard-earned money at the same time.

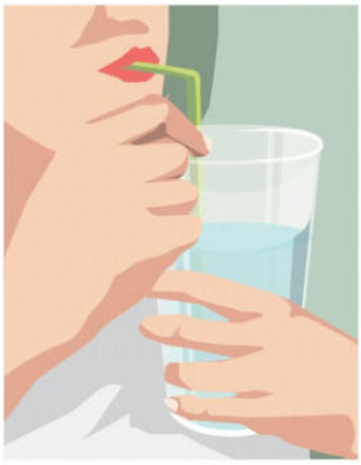
NEXT ISSUE
- Use a telescope
- Make a bubble in a bubble

Learn about sound waves

A simple experiment to show how sound travels and why it changes its pitch

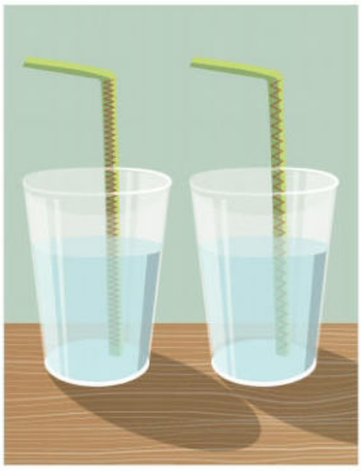
1 Prepare your experiment

Half-fill a glass with water and set it aside. Next, cut horizontally through a drinking straw around two-thirds of the way up. You want to be able to bend the smaller third at right angles without breaking the straw. Be prepared to have several goes at this before getting it right, as it is quite a delicate operation. Once you have successfully cut through the straw, place the larger part into the glass and bend the smaller part back.



2 Make some music

The smaller part of the straw should be bent so that when you blow through it, the airflow passes along the top of the straw. Blow gently into the tube. You should be able to hear a whistling sound. This sound is created as the air inside the larger part of the straw vibrates. The vibrating air travels down the straw, hits the water and bounces back up. Once out of the straw again, the sound waves expand, reaching your ear as a whistling noise.



3 Pitch up

To take the experiment further, see how the pitch changes as you increase or decrease the volume of water in the glass. You should notice the pitch gets higher with more water in the glass. This is because the pitch of sound is determined by the speed of the vibrations. With more water in the glass, the straw is fuller and the vibrations have less time to stretch out. This increases the speed of the vibrations, making the sound that reaches your ear much higher.

In summary...

This is an easy way for you to understand the properties of sound and how it can be manipulated. Sound comes from vibrations and by speeding them up or slowing them down, we can make sounds higher or lower. This is something we do every day without realising it when we talk.

QUICK QUIZ

Test your mind with ten questions based on this month's content to win an amazing Airfix RAFBF 'Design-a-Hawk' model!

Answer the questions below and then enter online at **www.howitworksdaily.com**

1. From which city will Solar Impulse 2 begin its round-the-world flight?
2. What is the name of the process by which bacteria reproduce?
3. In what year was the first industry-standard colour television approved?
4. Which future prime minister championed the Whippet tank?
5. What is the name of the gap in an enzyme where only specific molecules can fit?
6. How old was Louis Braille when he completed his Braille alphabet?
7. What type of cloud is most associated with thunderstorms?
8. What is the maximum speed a human can throw a baseball (in km/h)?
9. Which German island has the DHL company sent delivery drones to?
10. Which was the first iPhone model to include AI assistant Siri?

ISSUE 67 ANSWERS

1. Four hours and 12 minutes **2.** Orange **3.** 40 years **4.** Pillow lava **5.** 2022 **6.** Ivan the Terrible **7.** 206 **8.** 2-21 days **9.** Bletchley Park **10.** BAE Systems

INBOX
Speak your mind...

Get in touch
Want to see your letters on this page? Send them to...

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

WIN!
We enjoy reading your letters every month, so keep us entertained by sending in your questions and views on what you like or don't like about the mag. You may even bag an awesome prize for your efforts!

AMAZING PRICE FOR NEXT ISSUE'S LETTER OF THE MONTH!

CAPTURE AMAZING VIDEO FOOTAGE

It may look small but it is mighty. This Kodak video camera records 1080p HD video and has a button for instant social media uploading.

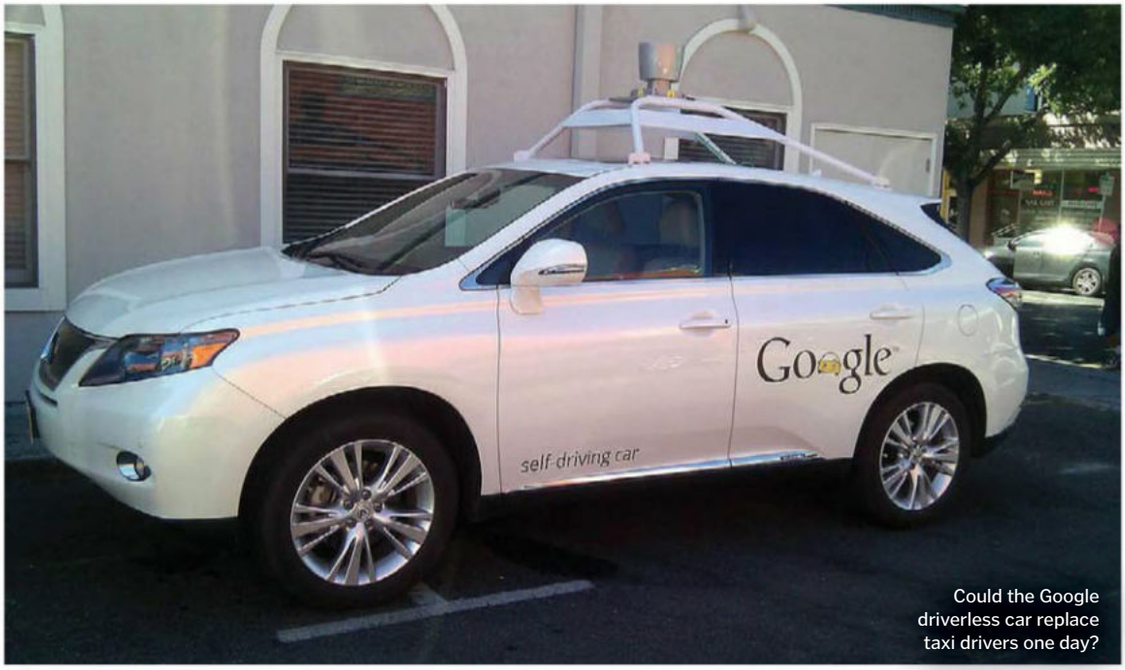
Letter of the Month

Rise of the machines

Dear **HIW**,

Reading through issue 67 I was struck by how many jobs can be rendered obsolete by advancements in technology. I love technology and have a background in computing, but it is sad to think that people can lose their livelihoods to and be replaced by machines. Of course, this is not a new phenomenon, as shown by the article on combine harvesters (pg 39), which replaced the jobs of many manual workers in the 19th century. But the pace of change is rapidly increasing. Take these examples from the magazine: delivery drones (pg 15) could threaten van drivers and postmen; driverless taxis (pg 15) threaten taxi drivers; domestic robots (pg 17) threaten domestic employees; car manufacturing robots (pg 34), assembly-line workers; and driverless tube trains (pg 38), train drivers. The threat is real, and not just for manual workers: estate agents must fear online estate agencies, accountants must worry how soon they'll be replaced by a suite of programs, and airline pilots are fast becoming little more than bystanders as the automatic systems do more of the work. The list is endless and growing all the time. The prospect of mass civil unrest is, frankly, frightening. **David Moss**

You're right, Alan, it is incredible to think how many human jobs might be in the hands of robots within the next century. Here at HIW we love to champion new technology that is going to make our lives easier, but we acknowledge the dangers of becoming over-reliant on technology. If even Stephen Hawking is worried about the rise of artificial intelligence, it must be a legitimate concern! But we're hoping the rise of working robots will benefit us in the long term. With robots performing manual roles, more humans will be at liberty to solve the world's bigger problems. Robot workers could free us to create fuel-efficient transport, end world hunger and maybe even invent the teleporter!



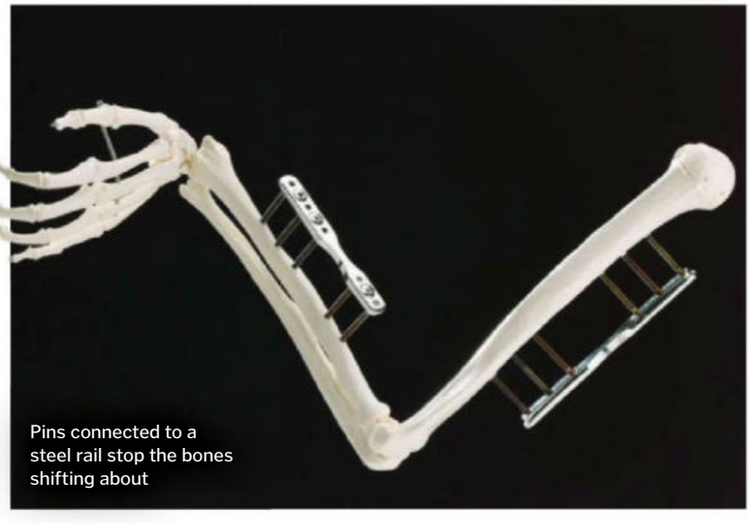
Could the Google driverless car replace taxi drivers one day?

Total fixation

Dear **HIW**,

Let me start off by saying how much I enjoy reading **How It Works**, every month it never fails to impress me! I have always been interested in the human body. But one thing in particular amazes me: external fixation. I think it's amazing how we have found a way to lengthen and regenerate bones and the fact it can be used to heal fractures and bone defects all at the same time. So my question is, how does this ingenious method work? **Adam Bennett**

It's a really strange practice, Adam, but it essentially works by pulling a bone apart and letting it regrow. Pins are inserted into the bone above and below a deliberately made fracture and held steady by an external rail. These pins tug at either end of the bone, gradually pulling it apart. Cells grow to fill this gap making the bone slightly longer. External fixation also helps fractures heal by holding the two parts of a broken bone in place while it mends. All in all, it sounds pretty painful, don't you think?



Pins connected to a steel rail stop the bones shifting about

Plate expectations

Dear **HIW**,

You said in issue 66 that the continents in 250 million years will have formed into one supercontinent. My question is; what happens then? If the tectonic plates have moved all the continents into one another where do they go from there? Will the tectonic plates stop moving or keep going

After the continents collide we could see enormous mountain ranges and new island formations

© Science Photo Library

"We don't know what would happen when we got sucked in, but we wouldn't be able to see anything at all because no light can escape a black hole"

and form the landmass into one gigantic Mount Everest? Will the outer edges of the plates still produce landmass such as the Hawaiian islands for example?
Paul

That's a very good question, Paul. It is highly likely that when Africa and Europe collide a large mountain range will form along that line. The impact will create mantle plumes where extremely hot rocks push up through the mantle. This process will most likely force Pangaea Ultima apart again. Mantle plumes on oceanic plates create hot spots that can form new landmasses like Hawaii.

The hole truth

■ Dear **HIW**,
I am a big fan of How It Works and have been collecting them for over a year now, so thank you, it is worth every penny. I have a crazy question that randomly popped into my head after a physics lesson on star life cycles. What would happen if the universe were completely covered in black holes? I know next to nothing about black holes so I haven't a clue what would happen.
Thanks,
Patrick Clare

Thanks very much, Patrick! It's a pretty scary thought, but we would probably be left with just one enormous black hole. As galaxies collide, their black holes merge into one. As they get bigger, their gravitational pull increases, which will tug more black holes toward them. Unless they were all evenly spaced out and the same size, each one would get gobbled up until the universe is one big black hole. We don't know what would happen when we got sucked in, but we wouldn't be able to see anything at all because no light can escape a black hole.

What's happening on... Twitter?

We love to hear from **How It Works**' dedicated followers. Here we pick a few tweets that caught our eye this month...

Semantic Earth
Good #retweets and #news about #Geography on **@HowItWorksmag**

Paul Cooper
Gecko-inspired gloves let you scale walls of glass via **@HowItWorksmag**

RheaLeeMaria
@HowItWorksmag Why do men take portrait photos on the opposite side to women? Told this ages ago and it is true of me and my wife. Curious.

GreatDigitalMags
Click your way over to the Bookazines Facebook page for your chance to win a copy of **@HowItWorksmag** Amazing Animals.

Elasya Venter
@HowItWorksmag I read about quantum entanglement this weekend!

Daniel Poncsak
@HowItWorksmag I have a tough time finding your magazine in bookstores, but when I do, I scoop up one immediately. Love them all!

Naked Scientists
@HowItWorksmag Yew might be right! That one really had us stumped #treepuns

Glenn Jones
@HowItWorksmag
@NakedScientists I have a feeling that #treepuns may prove 'poplar.'

iMend
@HowItWorksmag Exciting news! @imenddotcom have been featured on **@HowItWorksMag**!

HOW IT WORKS

Imagine Publishing Ltd
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
☎ +44 (0) 1202 586200
Web: www.imagine-publishing.co.uk
www.howitworksdaily.com
www.greatdigitalmags.com

Magazine team

Editor Jodie Tyley
jodie.tyley@imagine-publishing.co.uk
☎ 01202 586215
Art Editor Andy Salter
Editor in Chief Dave Harfield
Research Editor Jackie Snowden
Senior Art Editor Helen Harris
Senior Staff Writer Jo Stass
Staff Writer Jamie Frier
Production Editor Erlingur Einarsson
Assistant Designer Hannah Parker
Photographer James Sheppard
Publishing Director Aaron Asadi
Head of Design Ross Andrews

Contributors
Sarah Bankes, Ed Crooks, Ella Carter Alexandra Cheung, Tom Connell/Art Agency, Alicea Francis, Shanna Freeman, Jack Griffiths, James Hoare, Laura Mears, Hayley Paterek, Peter Scott/Art Agency, Lee Sibley, Steve Wright, Luis Villazon

Cover images
Alamy, Dreamstime, Draganfly, Getty, Matternet, Parrot, Thinkstock, Trimble

Photography
Alamy, Corbis, DK Images, Dreamstime, Getty, NASA, Rex Features, Science Photo Library, Thinkstock, Wikimedia, Sol 90 Images. All copyrights and trademarks are recognised and respected.

Advertising
Digital or printed media packs are available on request.
Head of Sales Hang Deretz
☎ 01202 586442
hang.deretz@imagine-publishing.co.uk
Account Manager Jennifer Galvin
jennifer.galvin@imagine-publishing.co.uk
Sales Executive Luke Biddiscombe
luke.biddiscombe@imagine-publishing.co.uk

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities.
Head of International Licensing Cathy Blackman
☎ +44 (0) 1202 586401
licensing@imagine-publishing.co.uk

Subscriptions
subscriptions@imagine-publishing.co.uk
For all subscription enquiries
☎ 0844 815 5944
Overseas +44 (0)1795 418680
Email: howitworks@servicehelpline.co.uk
13 issue subscription (UK) – £41
13 issue subscription (Europe) – £50
13 issue subscription (USA) – £50
13 issue subscription (ROW) – £60

Circulation
Head of Circulation Darren Pearce
☎ 01202 586200

Production
Production Director Jane Hawkins
☎ 01202 586200

Founder
Group Managing Director Damian Butt

Printing & Distribution
Wyndeham Peterborough, Storey's Bar Road, Peterborough, Cambridgeshire, PE1 5YS

Distributed in the UK, Eire & the Rest of the World by: Marketforce, Blue Fin Building, 110 Southwark Street, London, SE1 0SU
☎ 0203 148 3300
www.marketforce.co.uk

Distributed in Australia by: Network Services (a division of Bauer Media Group), Level 21 Civic Tower, 66-68 Goulburn Street, Sydney, New South Wales 2086, Australia
☎ + 61 2 8667 5288

ISSN 2041-7322

Your daily dose of knowledge

For an endless supply of facts and answers, visit our trivia-packed website, updated every day

• Wall of knowledge • Interviews • Videos • Q&A • News • Top fives • Competitions • Fully annotated illustrations

www.howitworksdaily.com

History like you've never seen it before

ALL ABOUT HISTORY™

BUY YOUR COPY TODAY

Print edition available at www.imagineshop.co.uk

Digital edition available at www.greatdigitalmags.com

Available on the following platforms

Print Tablet Phone Desktop

facebook.com/ImagineBookazines twitter.com/Books_Imagine

NEXT ISSUE

Issue 69 on sale 5 February 2015

WORLD'S WEIRDEST WEATHER

The strangest phenomena on the planet explained

Counting down the world's smartest structures

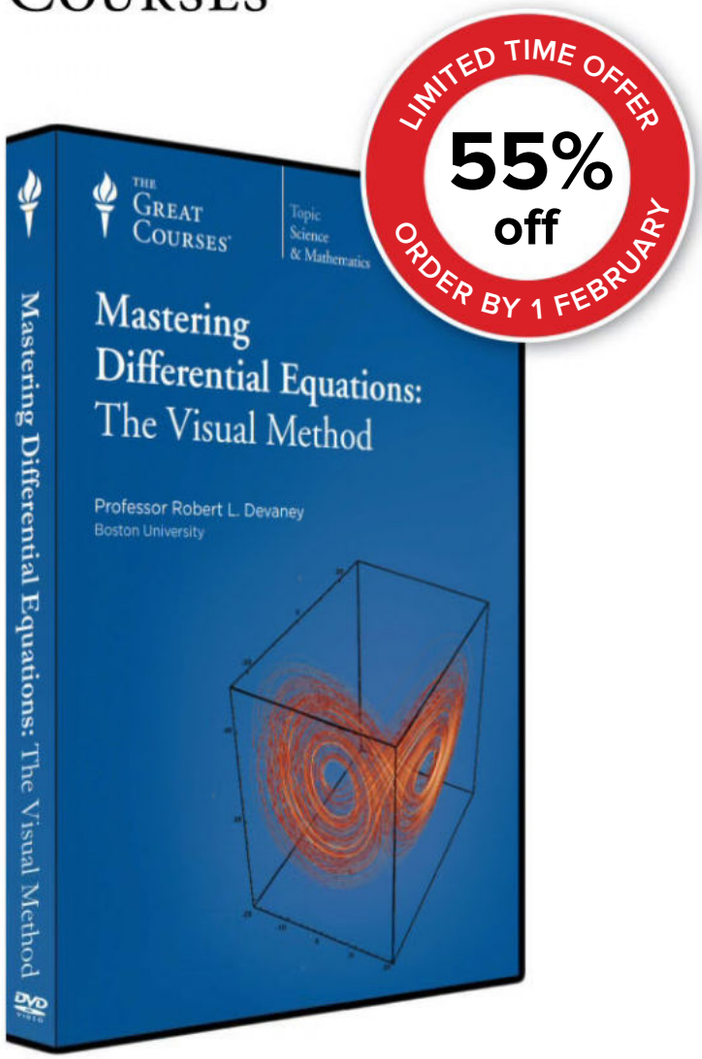
Discover the five most exciting exoplanets

Find out what fossils are and where to find them

How low temperatures are used to save lives

+LEARN ABOUT ■ ABU SIMBEL ■ ELECTRIC BIKES ■ FOREST FIRES ■ LIGHT WAVES ■ 3D PENS ■ WEIGHT LOSS

THE GREAT COURSES®



Master Differential Equations

For centuries, differential equations have been the key to unlocking nature's deepest secrets. But now, with the aid of easy-to-grasp computer graphics, a highly visual method exists that can start a committed learner on the road to finally mastering this beautiful application of the ideas of calculus.

Mastering Differential Equations: The Visual Method takes you on this amazing mathematical journey in 24 intellectually stimulating and visually engaging lectures delivered by Professor Robert L. Devaney—a pioneer of this visual approach. Throughout this course, you'll cover first- and second-order differential equations, linear and nonlinear systems, chaos theory, dynamical systems, fractals, and more.

Offer expires 01/02/15

THEGREATCOURSES.CO.UK/4HIW

0800 298 9796

Mastering Differential Equations: The Visual Method

Taught by Professor Robert L. Devaney
BOSTON UNIVERSITY

LECTURE TITLES

1. What Is a Differential Equation?
2. A Limited-Growth Population Model
3. Classification of Equilibrium Points
4. Bifurcations—Drastic Changes in Solutions
5. Methods for Finding Explicit Solutions
6. How Computers Solve Differential Equations
7. Systems of Equations—A Predator-Prey System
8. Second-Order Equations—The Mass-Spring System
9. Damped and Undamped Harmonic Oscillators
10. Beating Modes and Resonance of Oscillators
11. Linear Systems of Differential Equations
12. An Excursion into Linear Algebra
13. Visualising Complex and Zero Eigenvalues
14. Summarising All Possible Linear Solutions
15. Nonlinear Systems Viewed Globally—Nullclines
16. Nonlinear Systems near Equilibria—Linearisation
17. Bifurcations in a Competing Species Model
18. Limit Cycles and Oscillations in Chemistry
19. All Sorts of Nonlinear Pendulums
20. Periodic Forcing and How Chaos Occurs
21. Understanding Chaos with Iterated Functions
22. Periods and Ordering of Iterated Functions
23. Chaotic Itineraries in a Space of All Sequences
24. Conquering Chaos—Mandelbrot and Julia Sets

Mastering Differential Equations:
The Visual Method
Course no. 1452 | 24 lectures (30 minutes/lecture)

SAVE £30

DVD ~~£54.99~~ NOW £24.99
+£2.99 Postage and Packing
Priority Code: 110702

For 24 years, The Great Courses has brought the world's foremost educators to millions who want to go deeper into the subjects that matter most. No exams. No homework. Just a world of knowledge available anytime, anywhere. Download or stream to your laptop or PC, or use our free mobile apps for iPad, iPhone, or Android. Nearly 500 courses available at www.TheGreatCourses.co.uk.